This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

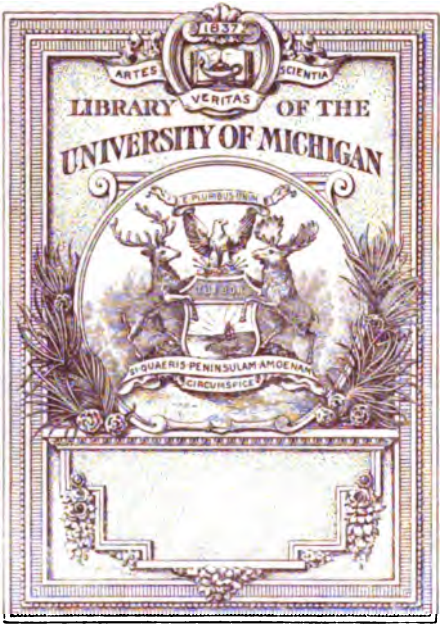
+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

B 489133

Digitized by Google



Digitized by Google

Digitized by Google

Digitized by Google

THE

SCHOOL OF MINES QUARTERLY,

A

JOURNAL OF APPLIED SCIENCE.

VOL. XXVII.

NOVEMBER, 1905, TO JULY, 1906.

COLUMBIA UNIVERSITY,

NEW YORK CITY.

1906.

Digitized by Google

Science Library

BOARD OF EDITORS.

A. J. MOSES, Prof. of Mineralogy.
J. F. KEMP, Prof. of Geology.
R. E. MAYER, Adj. Prof. of Drawing.
E. WALLER, Analytical Chemist.
W. H. FREEDMAN, E.E.
T. H. HARRINGTON, Tutor in Drawing.

Managing Editor, R. E. MAYER.
Business Manager, T. H. HARRINGTON.

Digitized by Google

Natural Resources
Transfer
c 24/74
Science Library
5-28-54

THE SCHOOL OF MINES QUARTERLY.

INDEX, VOL. XXVII.

November, 1905, to July, 1906.

All Abstracts are printed in Italics, and those relating to Chemical Analysis appear only under the heading Analytical Chemistry.

ALUMNI AND UNIVERSITY NEWS.

Departments:

PAGE

Chemistry 77
Civil Engineering 81,360
Electrical Engineering 82
Summer School of Mining 75

Analytical Chemistry, Abstracts. By Elwyn Waller.

Absorbing Carbon Dioxide for Weighing 254
Ammonia in Waters 244
Antimony — Electrolytic Separation from Tin 248
Asphalt Adulterations 256
" *Testing* 256
Bismuth as Phosphate 247
" *Determinations* 248
Carbon Dioxide — Indirect Determination 254
Chili Saltpetre 254
Chlorates and Bromates 251
" *Bromates and Iodates* 251
Chlorides, Bromides and Iodides 251
Cleansing Metal Apparatus 244
Columbium — Qualitative 249
Copper by the Iodine Method 246
Cyanates — Volumetric 255
Distinguishing Calcite from Dolomite 245
Electrolytic for Lead and Copper 247
" *Separation of Nickel from Zinc* 246
Estimation of Oil in Water from Condensing Engines 256
Ferrous Oxalate for Standardizing 244
Fluorspar Analysis 253
Gold — Precipitation as Metal 248

153744

Digitized by Google

Gold — Quantitative Separations 249
Iron, Aluminum or Chromium from Magnesium or from manganese, zinc, nickel, copper, etc 245
Iron and Aluminum 245
" *in Pyrolusite* 245
Lead as Sulphate 247
Lime Analysis. Sugar Test 245
Manganese in Cyanide Solutions 246
" *in Waters* 246
Mineral Phosphates in Phosphatic Slags 254
Nickel — Qualitative 246
Nitrates and Nitrites 255
Nitric Acid — Gravimetric 255
Organic Nitrogen in Potable Waters 256
Oxygen in Copper 256
Periodate as a Reagent 244
Phosphorus in Phosphor Bronze 254
Platinum and Iridium — Separation 249
Potassium. New Reagent 245
Separate Estimation of Hydrofluoric and Sulphuric Acids 253
Separating Arsenic from Antimony, etc. 248
Separation of Thorium 249
" *of Tungstic, Vanadic and Silicic Acids* 250
Silica — Separation from Fluorine 253
Silicon in Irons 253
" *in Steel (rapid process)* 253
Sodium — Modification of Fremy's Reagent 244
Sulphur in Blendes and Zinc Products 252
" *in Coal* 252
" *in Iron and Steel* 251
" *in Oils — liquid fuels* 252
Tellurous and Telluric Acid 250
Thoria — Separation from the Yttrium Cerium Group 249
Thorium and Iron from Uranium 249
Tin in Alloys, Bronzes, etc 248
Tungsten in Ores 250
Watson-Lunge Method 252
Zinc in Zinc Aluminum Alloys 246
Zirconium and Titanium in Minerals 250
" *Qualitative* 250
Advantages and Applications of the Electric Drive. By F. B. Crocker and M. Arendt 61
Air Blasts, Stresses in the Country Rock as the cause of, in the Mines at Pribram, Bohemia. By H. Stefan 423
American Law Relating to Minerals. By C. H. Shamel 1
Application of Metallography to Opaque Minerals. By W. Campbell 414
ARENDT, M. AND CROCKER, F. B. *Advantages and Applications of the Electric Drive* 61
BATES, PUTNAM A., *Isolated Plant Engineering* 269
BLEICH, S. D , *Internal Stresses in Masonry* 33

Digitized by Google

BOOK REVIEWS:
American Telephone Practice. By Kempster B. Miller..... 85
Cement and Concrete. By Louis Carlton Sabin..... 85
Cements, Limes and Plasters; their Materials, Manufacture and Properties. Edwin C. Eckel 84
Copper Mines of Lake Superior. By T. A. Rickard..... 84
Cyanide Industry, Theoretically and Practically Considered. By R. Robine and M. Lengler. Translated by J. A. Le Clerc 363
Earth and Rock Excavation, a Practical. By Charles Prelini..... 258
Economics of Mining. By T. A. Rickard, W. R. Ingalls, H. C. Hoover, R. G. Brown and other specialists..... 260
Electric Transmission of Water Power. By A. S. Adams 461
Experimental Electrochemistry. By N. Monroe Hopkins 364
Experimental Researches on the Constitution of Hydraulic Mortars. By Henri Le Chatelier. Translated by Joseph Lathrop Mack..... 262
Hand Book of Metallurgy. By Carl Schnabel. Translated by Henry Louis. 266
High Tension Power Transmission 86, 461
Laboratory Guide to the Study of Qualitative Analysis Based upon the Application of the Theory of Electrolytic Dissociation and the Law of Mass Action. By E. H. S. Bailey and Hamilton P. Cady..... 261
Manual of Chemical Analysis as Applied to the Assay of Fuels, Ores, Metals, Alloys, Salts, and other Mineral Products. By Eugene Prost, Translated by J. J. Cruickshank Smith 263
Minerals in Rock Sections. Revised edition. By Lea McIlvane Luquer... 264
Nature of Ore Deposits. By Richard Beck..... 257
New Knowledge. By Robert Kennedy Duncan..... 263
Notes on Electrochemistry. By F. G. Wiechman 363
Production of Aluminium and its Industrial Use. By Adolphe Minet. Translated, with additions, by Leonard Waldo..... 265
Pyrite Smelting. Edited by T. A. Rickard..... 83
Select Methods in Food Analysis. By Henry Leffmann and William Beam. 264
Technical Methods of Ore Analysis. By Albert H. Low..... 261
CAMPBELL, WILLIAM. *Application of Metallography to Opaque Minerals*..... 414
Cane Sugar Factories; Chemical Control of. By W. D. Horne..... 128
Chemistry, Analytical Abstracts, see Analytical Chemistry. Abstracts.
Constitution of Quinine. By B. L. Murray..... 39
CROCKER, F. B. AND ARENDT, M. *Advantages of the Electric Drive*..... 61
Crushing Machinery, Effect of Variations in the speed of, upon the Production of Undersized Material. By H. W. Gartrell..... 28
Crystal, Determination of the Geometrical Constants of a, from its Interfacial Angles. By A. J. Moses..... 432
Dams, Internal Stresses in Masonry. By S. D. Bleich..... 33
Determination of Minerals in Crushed Fragments by Means of the Polarizing Microscope. By A. F. Rogers..... 340
Determination of the Geometrical Constants of a Crystal from its Interfacial Angles. By A. J. Moses 432
Development, Historical, of General Chemistry. By W. Ostwald.....87, 313, 388
Drive, Advantages and Applications of Electric. By F. B. Crocker and M. Arendt..... 61
Effect of Variations in the Speed of Crushing Machinery upon the Production of

Digitized by Google

Undersized Material. By H. W. Gartrell..... 28
Electric Drive, Advantages and Applications of the. By F. B. Crocker and M. Arendt..... 61
Engineering, Isolated Plant, By P. A. Bates..... 269
Fossils, North American Index. By A. W. Grabau and H. W. Shimer..... 138
GARTRELL, H. W. *Effect of Variations in the Speed of Crushing Machinery upon the Production of Undersized Material*..... 28
Geology of Pioche, Nevada, and Vicinity. By Fred J. Pack..... 285, 365
GRABAU, AMADEUS W. AND SHIMER, HERVEY WOODBURN. *North American Index Fossils*..... 138
Historical Development of General Chemistry. By W. Ostwald.....87, 313, 388
HORNE, WILLIAM D. *Chemical Control of Cane Sugar Factories*..... 128
Index Fossils, North American. By A. W. Grabau and H. W. Shimer..... 138
Internal Stresses in Masonry Dams. By S. D. Bleich..... 33
Isolated Plant Engineering. By Putnam A. Bates..... 269
Masonry Dams, Internal Stresses in. By S. D. Bleich..... 33
Metallography, Application of, to Opaque Minerals. By W. Campbell..... 414
Minerals, American Law Relating of. By C. H. Shamel..... 1
" Application of Metallography to Opaque. By W. Campbell..... 414
Minerals, Determination of, in Crushed Fragments by Means of the Polarizing Microscope. By A. F. Rogers..... 340
Mines, Stresses in the Country Rock as the Cause of Air Blasts in the, at Pribram, Bohemia. By H. Stefan..... 423
MOSES, ALFRED J. *Determination of the Geometrical Constants of a Crystal from its Interfacial Angles*..... 432
MURRAY, BENJAMIN LINDLEY. *Constitution of Quinine*..... 39
Nevada, Geology of Pioche, and Vicinity..... 285, 365
North American Index Fossils. By A. W. Grabau and H. W. Shimer..... 138
Opaque Minerals, Application of Metallography to. By W. Campbell..... 414
OSTWALD, WILHELM. *Historical Development of General Chemistry*....87, 313, 388
Over-Winding in Hoisting Operations. By R. Peele..... 118
PACK, FRED. J. *Geology of Pioche, Nevada, and Vicinity*..... 285, 365
PEELE, ROBERT. *Over-Winding in Hoisting Operations*..... 118
Pioche, Geology of, Nevada, and Vicinity. By F. J. Pack.....285, 365
Polarizing Microscope, Determination of Minerals in Crushed Fragments by Means of the. By A. F. Rogers..... 340
Quinine, Constitution of. By B. L. Murray..... 39
ROGERS, AUSTIN F. *Determination of Minerals in Crushed Fragments by Means of the Polarizing Microscope*..... 340
SHAMEL, CHARLES H. *American Law Relating to Minerals*..... 1
SHIMER, HERVEY WOODBURN and GRABAU, AMADEUS W. *North American Index Fossils*..... 138
Speed, Effect of Variations in the, of Crushing Machinery upon the Production of Undersized Material. By H. G. Cartrell..... 28
STEFAN, HUGO. *Stresses in the Country Rock as the Cause of Air Blasts in the Mines at Pribram, Bohemia*..... 423
Stresses, Internal, in Masonry Dams. By S. D. Bleich..... 33
" in the Country Rock as the Cause of Air Blasts in the Mines at Pribram, Bohemia. By Hugo Stefan..... 423
Sugar Cane. See Cane Sugar.
WALLER, ELWYN. *Analytical Chemistry. Abstracts*..... 244

Digitized by Google

THE

SCHOOL OF MINES QUARTERLY.

VOL. XXVII. NOVEMBER, 1905. No. 1.

THE AMERICAN LAW RELATING TO MINERALS.

BY CHARLES H. SHAMEL, M.S., L.L.B., A. M.

The extraordinary industrial expansion of the past century has resulted in the creation of numerous branches of the law such as railroad law, the law of the electricity and electric wires, of medical jurisprudence, of legal chemistry, etc., directly connected with industrial and scientific development. Being one of the most important divisions of industrial activity and involving many peculiar conditions, there has naturally developed along with these other branches of law, a system of mining law. Owing to its vast and varied mineral resources, the peculiar early social and political conditions of parts of its territory, and its dual system of government, this development of mining law has been greater in the United States than in any other nation.

Now mining deals as an art with the same natural objects with which geology deals as a science so that, as we might reasonably expect, a considerable part of mining law directly involves geological facts and principles. But in the United States, owing to the fact that in the most important part of our mining legislation, geological terms are used in defining legal rights and that certain geological conceptions have formed the basis of parts of the law, there exist, unique and important applications of the science of geology to practical jurisprudence, and in mining litigation geologists are called upon for assistance as experts just as experts in medicine, chemistry and electricity are summoned in criminal and industrial litigation. I shall attempt, therefore, an exposition of that

Digitized by Google

part of American mining law that deals with the definitions and the legal conception of the terms, mineral, ore, etc., as used in law; for such use involves geological principles either by implication or directly.

To understand the trend and force of the decisions of the various courts on this subject, a statement is necessary of the peculiar territorial divisions of the United States with respect to the application of the various principles of mining law.

First. There are the thirteen original states and those carved out of territory claimed by them, to which may be added Tennessee and Texas. In this group the individual state was the paramount proprietor of mineral lands and hence the sole source of law regarding mining and the cases are decided either according (1) to the general principles of the common law system or (2) according to the laws enacted by the state legislatures.

Second. In the States of Illinois, Indiana, Iowa, Missouri, Michigan, Minnesota, Wisconsin, and Arkansas, government land containing lead, copper, etc., was, by Acts of Congress, ordered sold under special laws enacted prior to the legislation that resulted from the immense discoveries of gold in California. By various acts of Congress, land belonging to the United States in Alabama, Michigan, Minnesota, Wisconsin, Kansas and Missouri was excepted from the operation of the federal mining laws that apply in the next group of states. In this second group of states the common law and state legislation are the chief sources of mining law with perhaps a few traces of law from federal legislation.

Third. All the remaining territory of the United States in which, being acquired at different times by the National government, the Nation was the paramount proprietor of the mineral lands so that the laws governing the same are chiefly derived from federal legislation, although common law, state legislation and even local customs are important sources of the rules of mining law. The provisions of the federal mining laws were extended to the district of Alaska by the Act of May 17, 1884, and June 6, 1900.

Under an Act of Congress passed July 1, 1902, and amended February 5, 1905, provision was made for the location of mining claims in the Philippine Islands, "upon land containing veins or lodes of quartz or other rock in place, bearing gold, silver, cinnabar lead, tin, copper, or other valuable deposits" and by another section provision is made for "entering" coal land, and in still another

Digitized by Google

section for the sale of saline lands. Not being able to find any reference to mining rights in Porto Rico in the U. S. statutes, I addressed a letter of inquiry concerning the same to the governor of Porto Rico, and in reply received the following which give the status of mineral rights so concisely that I quote verbatim:

"In answer to your letter of the 7th instant, concerning the mining laws of Porto Rico, I desire to say that the old Spanish mining laws have been considered repealed by the various codes adopted since the American occupation, and that there is now no special mining law. Under Section 357 of the Civil code adopted in 1902, the owner of the surface owns everything beneath the surface, hence it is not our custom, as it is in Venezuela, to regard the mining rights as separate from the surface ownership.

Mines on lands belonging to the Insular Government are exploited under a concession, and I have to-day asked the Commissioner of the Interior to inform you of the terms on which such concessions may be granted. There are about eighty such concessions now in force.

Very respectfully,

MARTIN E. GILL,
Acting Secretary.

The section of the Civil Code referred to above reads as follows:

SECTION 357. The owner of a parcel of ground is the owner of its surface and of everything under it, and he can construct thereon any works or make any plantations and excavations which he may deem proper, without detriment to the usufructs legally established thereon.

In a second letter Mr. Gill says:

"In continuance of my letter of the 29th ultimo, I desire to say that the Commissioner of the Interior informs me that mining concessions and rights under the law as it existed during the time of the occupation of this island, were acquired in the same manner as in Cuba and Mexico. At present, however, the proprietor of the surface owns everything beneath the surface, subject to mining rights which may have been granted during the Spanish occupation. The Commissioner goes on to say: 'You might add that the mining industry here is a little less than feeble.'"

The treatment of this subject may be subdivided into the following heads:

Digitized by Google

I. Legal interpretation of the terms ores, minerals, etc., as made, or used in deeds, leases, contracts, etc., under the common law and state legislation. Cases under this subdivision may arise in any state, but the majority are furnished by the states comprised in the first two groups, for in the third group the mining litigation is usually governed by federal laws.

II. Interpretations by the courts and United States Land Department under the Federal mining and land laws as to what constitutes minerals within the meaning of these laws. Under this subdivision the cases are of course, confined to the third group.

III. Interpretations of the terms relating to minerals, ores, etc., arising under the United States customs laws.

In the first two groups of states the ownership of the surface, by the principles of the common law, carries with it the right to all that was beneath, limited by planes through the boundaries extended toward the center of the earth, except in New York, where the state asserts its ownership of all mines of the precious metals by virtue of its sovereignty. But by deed, lease or contract the ownership of the minerals beneath the surface could be severed from the fee, and considerable litigation has arisen from disputes over the interpretation of the terms used in such instruments, resulting in a fairly uniform body of law on this branch of the subject.

The most frequent causes of litigation have appeared in cases where a grant, lease, or contract was made conveying "minerals," "minerals and ores," etc. The earliest case that I have found involving the definition of the word mineral in Americal legal decisions is that of Gibson *vs.* Tyson, decided in Pennsylvania in 1836.* The dispute in this case was whether or not the phrase "all minerals or magnesia of any kind" in a reservation in a deed, included chromate of iron, and the court decides that chromate of iron is a mineral within the meaning of the words of the reservation, although this decision seems to be based to some extent on evidence in the case tending to show that the parties at the time the instrument was executed regarded the particular substance as a mineral. The court says: "But it has been objected that according to the ordinary and common acceptation of the term mineral, chrome is not included with the exception because, although properly a mineral, yet, not being a metallic substance, it is not consid-

* 5 Watts, 34.

Digitized by Google

ered by the great mass of mankind as a mineral and embraced within that term. This objection would certainly have great weight, and perhaps could not be easily overcome, were it not for the parol evidence and the facts established by it. This evidence, however, shows, very clearly, that it was that which is now known to be chrome, that on the first taking up of the land in which it was found, gave to it the name of mine land; that it was thought to be a metallic ore of some kind, and spoken of frequently as containing some gold ore or silver."

The leading case however among the early adjudications on this subject seems to be Hartwell *vs.* Camman * decided in New Jersey in 1854. It squarely decides that it is not necessary for a substance to contain a metal to be embraced within the term "mineral."

As it is frequently cited in most subsequent similar cases, this justifies an outline of the decision. Hartwell conveyed to Camman by an ordinary warranty deed "all mines and minerals open, or to be opened, with free ingress and egress to the same for the purpose of mining in all its various branches," in a tract of land. It appears that at the time of this conveyance the land was believed to contain workable copper ore and excavations were made in search thereof. Failing to find workable copper ore, but discovering in the exploration near the surface a "hard red substance like red shale," Camman proceeded to mine it and grind it into paint. The grantor brought suit for an injunction to stop such mining on the ground that the substance mined and ground into paint was not included in the grant. In deciding the case the court says as to the character of the mineral: "It is a substance resembling in general appearance red shale, so soft as to be easily cut with a knife when first excavated, but differing in appearance and quality from the surrounding earth. It is found in regular strata or boulders of various sizes. * * * When broken up and ground it is used as a paint and is valuable for that purpose." The court then states that it was gotten out by the ordinary methods of mining and says in regard to the expert testimony in the case: "Professor Doremus was the only scientific witness examined." He says "it may be called an argillaceous sandstone, alumina and silica being the prominent ingredients — it is not an iron ore. This comes under the head of argillaceous rock. I wish to distinguish

* Hartwell *vs.* Camman, 10 N. J. Equity, 128.

Digitized by Google

these classes of ores or metalliferous rocks. The position of this paint material, as it lies in the mountain is not in veins but in strata. The extracting of this material as I saw it there, would not be called mining," and proceeding with the opinion says: "If the term mines and minerals used in the deed, could, by any fair construction, be confined to metallic substances the question involved would be easy of solution; for the metallic property found in this paint stone is so small that for the purpose of extracting the metal it is of no value. But I do not think the terms should be confined to metals or the metallic ores. * * * It is embraced in the definition given by men of science of the term mineral." In Bakewell's Mineralogy, page 7, it is said the term mineral, in common life, is generally applied to denote substance dug out of the earth or obtained from mines. In Cleveland's Mineralogy, page 1, the definition is given thus: 'Minerals are those bodies which are destitute of organization, and which naturally exists within the the earth or at its surface.' My conclusion is that this paint stone passed by the grant, and that the defendants have a right to excavate and remove it and to convert it to their own use."

It was not long after the disposal of the above case that the New Jersey courts were called upon to wrestle with perhaps the most noted litigation that has ever arisen in the United States directly involving mineral definitions, lasting in varying forms for nearly half a century. This was concerning the franklinite deposits near Franklin Furnace, New Jersey. The character of those parts of the deposit affected by the litigation as shown to the court, is described in the parts of the opinion of the court quoted below. The importance and irrepressible character of the litigation, the inherent difficulties of the case as well as interesting features of some of the opinions of the various courts as they labored with scientific difficulties of the subject, complicated by heroic efforts to right the supposed injustice attempted through alleged overreaching use of scientific distinctions and terms by certain early practitioners of "high finance" justify a somewhat extended statement of the litigation and citations from the opinions of the courts.

The possibility of this litigation was caused by Samuel Fowler who in 1848, being the owner of the Mine Hill tract of land conveyed to the Sussex Zinc and Copper Mining and Manufacturing Company "all the zinc, copper, lead, silver and gold ores and also all other metals or ores containing metals (excepting the metal or

Digitized by Google

ore called franklinite and iron ores, when it exists separate from the zinc)." On the same day by another deed Fowler conveyed to the same company "all the metal, mineral, or iron ore, usually designated and known as franklinite, found or to be found in a certain tract of land" which tract of land was a *part* of the land conveyed in the first deed. This second deed did not affect any part of the tract of land in dispute but is referred to by the court as showing the understanding by the parties of the terms used. The Sussex Company in 1852 conveyed to the New Jersey Zinc Company, "all the zinc and other ores, *except franklinite and iron ores*" in the premises originally conveyed by Fowler to said Sussex Company, and also by a second deed "all the metal, mineral, or iron ore, usually known or designated by the name franklinite found or to found, etc.," in the same tract of land that Fowler had made similar conveyance of to said Sussex Company.

The terms used in this second deed between the two companies were identical with those of the Fowler deed to the second tract of land but as to the first deed between the two companies it will be observed that the language is not the same, for in the deed from the Sussex Company to the New Jersey Zinc Company the reservation was of "franklinite and iron ores" without the addition of the limiting word "when it exists separate from the zinc, consequently as to the first deed the interest conveyed to the New Jersey Zinc Company was not quite so extensive as the interest conveyed by Fowler to the Sussex Company. *All* the franklinite and iron ore was excepted whereas in the conveyance by Fowler only the franklinite and iron ore were excepted "*when it exists separate from the zinc.*"

This residual interest (all the franklinite or iron ore mixed with zinc) of the Sussex Company passed to another corporation, the New Jersey Franklinite Company. The New Jersey Franklinite Company proceeded to mine the franklinite ore that they owned and in 1857 the New Jersey Zinc Company attempted to enjoin the New Jersey Franklinite Company * from further mining and removing of ore on two grounds (1) that the reservation of all the franklinite in the deed by the Sussex Company was fraudulent, which contention was decided against it by the court, and (2)

* While this litigation was pending the title of the New Jersey Franklinite Co. passed by foreclosure of a mortgage to the Boston Franklinite Co., which became a party to the litigation as mentioned later in the opinion of the Court.

Digitized by Google

(with which we are particularly interested in this connection) that the ore in question was a zinc ore which passed by the terms of the grant to the New Jersey Zinc Company. On this branch of the case the court said: "The incontrovertible fact is that the mass consists of zinc ore and franklinite in such close mechanical combination that neither can be taken from the mine without removing the other, which party by the terms of the deed has title? Each party claims the entire mass, one or the other must take it. * * * The ownership of the property is in no sense joint. No partition of their interest could be made. One or the other must be entitled to it. The deeds were not intended to convey, and do not convey, distinct interest in the same lode, vein, or stratum. Some test must be applied by which the title to each vein or distinct portion of a vein can be ascertained to belong to one or the other of the parties.

It is satisfactorily shown by the evidence tha, at the date s of the deeds in which this controversy has its origin, and as late as the year 1853, the masses or veins of ore upon Mine Hill were regarded and known as franklinite. The ore was so called by the proprietors of the mines and by the miners themselves. It was so described in scientific treatises and in geological reports. It was so classified and arranged in mineralogical cabinets and exhibitions. The mass was known not to consist entirely of that mineral. Pure specimens or crystals of franklinite were known to exist only in small and unimportant bodies, having no value for practical purposes. In the general mass of the ore, there was mingled with the franklinite, ores of zinc and other minerals in various proportions. But so far as was known, franklinite constituted the predominating element which gave character and title to the mass. Zinc ore had been discovered and used in at least one locality, but no well defined vein of zinc ore had been developed. Upon Sterling Hill, in the immediate vicinity, distinct, well defined veins of zinc and franklinite had been developed, and the zinc vein extensively worked. Here, as on Mine Hill, the ores were found to some extent in mechanical combination. Both veins contained more or less of each mineral. In the zinc vein the red oxide of zinc predominated; it formed the enveloping mass which gave name and character to the ore, and though grains of franklinite were found extensively disseminated throughout the mass, it was universally known and designated as zinc ore. On Stirling Hill, the

Digitized by Google

separate lodes, though in immediate contact, were generally well defined and distinguished by clear lines of demarcation. From the general geological character of the vicinity, it was anticipated that, in the progress of investigation, a similar distinct and well defined vein of zinc ore would be developed upon Mine Hill. Upon this state of facts within the knowledge of parties, there seems to be no room for rational doubt as to what the parties intended by the terms used in the deed as descriptive of the subject matter of the conveyance. By "zinc ores" was meant those veins of lodes in which the ore of zinc was the predominating ore, and franklinite, not the pure mineral of that name, which was never found except in small and detached specimens, but those veins are lodes in which franklinite predominate, and which was known and designated as franklinite ore. The instrument must be construed according to the mind and intent of the parties at the time it was executed. * * * The evidence abundantly shows that the term franklinite was in constant and familiar use to designate the ore or mass in which the mineral predominated." This decision would seem to be based on sound legal and scientific reasoning, so far as it related to the interpretation of the terms of the deed conveying the mineral. However the case was appealed to the higher court and the decision of the chancellor was overruled.*

In the Court of Errors and Appeals the want of good faith in not executing the deed by the Sussex Company so as to convey all its rights to the New Jersey Zinc Company as had previously been agreed, seemed to appeal very strongly to this higher court; and by a divided vote (7 to 5) the decision of the chancellor was reversed and it was adjudged that the whole of the deposit belong to the New Jersey Zinc Company.

It is a legal maxim that "hard cases make bad law" and the above cited opinion of the court is a striking instance for, in its endeavor to correct the injustice arising from the sharp practice of the Sussex Company in making the deed and obtaining an acceptance thereof and the negligence of the New Jersey Zinc Company, in accepting a deed that did not fully carry out the prior contract between the two companies, this court evolves a decision that is a masterpiece of legal hair splitting with however, doubtless, an honest intention of promoting what they regarded as essential justice. After stating various transfers of this residual in-

* New Jersey Zinc Co. *vs.* Boston, etc., Co., 15 N. J. Eq., 434.

Digitized by Google

terest reserved as above stated and the organization of the Boston Franklinite Company and the profits of the promoters thereby, the court becomes eloquent and says: "What oceans of money they made no one can tell. All this while this zinc company pursued its plodding way, building oven after oven, furnace after furnace, and factory after factory, expending in such improvements, upon the faith of this transfer of stock, over $300,000, besides the very large consideration money it had paid, forcing success along the hard road of industry, developing, according to the true intent of its charter the ore of zinc; manufacturing their pure snow-white paint for the calls of commerce and comfort, convenience and elegance of life. They were the workers in the hive — they were the silk-worms painfully weaving their shrouds of silken thread, while this franklinite company toils not, neither does it spin — not an ounce of its boasted franklinite has it ever yet yielded to the demands of commerce. It springs at once into the butterfly stage of its existence whose only object in life is to spread its golden wings to the glittering sunshine and multiply its worthless species."

The court then proceeds to discuss the question of what the parties intended by the exception in the deed but leaving entirely out of account two facts that the chancellor states were established by evidence before him, (1) that in the similiar deposit on Sterling Hill that a large deposit of red oxide of zinc had been found and, being close together, therefore the parties probably supposed the same condition to exist in the two deposits, and (2) that the difference between the terms of the contract and the deed were discussed between the directors of the two companies at the time the deed was accepted, so that they must have known that when franklinite was excepted from the grant something was meant by it. But the court nevertheless proceeds "what, then, was meant by the parties at the time they used the term zinc ores in this deed? Did they mean this vein in dispute? * * * The evidence also shows that there were no other ores on the premises except this vein of franklinite and iron ores, and all the parties well knew it. Now, may we not ask, if it was not the intention to convey this vein by the name of a zinc ore, what did the parties intend it to be? It is apparent, that if they did not intend to convey this vein by the name of a zinc ore it must have been the intent of both parties to convey nothing. I think these facts show that it must have been the intent to convey this vein by the name of a zinc ore, for there

Digitized by Google

is nothing else upon which the deed could operate, and both parties must have known it. There is nothing upon this property but this vein of franklinite and iron ore. The franklinite and iron ore are excepted in terms, and if this vein was meant to be excepted as franklinite the deed conveys nothing as both parties must have known. Under these circumstances, we can draw no other conclusion than that the parties meant to convey something by the deed, and that could only, as both parties must have known, have been the vein in question. * * * But it is urged that the evidence shows that, at the date of the deeds, and as late as 1853, the mass or veins of ore in Mine Hill were regarded and known as franklinite, that the ore was so classified and arranged in mineral cabinets and exhibitions; that it was described in scientific treatises, geot logical reports, and was so called by the proprietors of the mines and by the miners themselves. But what do all these amount to if it appears by the overwhelming weight of other considerations, some of which we have indicated, that the parties to the deed, at the very time of the execution, intended to convey the vein in question by the name of zinc." The "overwhelming" "considerations" "indicated" is the legal quibbling in the above citation. This entertaining court then proceeds to describe how Berthier in 1821 having received from "Doct Fowler, who was a learned mineralogist" specimens of the mineral found in Mine Hill, "resolved it into its elements and discovered that it was a new mineral species, and christened it by the name of franklinite, because it had first been found at Franklin Furnace, in Sussex County, New Jersey," and that this vein had been worked for zinc for sixty years but continues bitterly, "that the old acquaintance, zinc, was for some time, as is customory in such cases, overslaughed in the halls of the learned by this new born babe of science. * * * But this franklinite was the most useless iron ore that had been discovered. There it had laid for one hundred years within 300 yards of an iron furnace tortured in every shape that skill and avarice could put upon it to declare its hoped for usefulness, and the only thing ever successfully generated between it and the furnace was a *salamander*." Then this court proceeds to perpetually enjoin the Boston Franklinite Company from digging any of the franklinite ore in Mine Hill.

This settled the title to the south part of Mine Hill for a time but later, as mentioned in the case of Meredith *vs.* Zinc and Iron Co.,

Digitized by Google

55 N. J. Eq., 211 (at p. 215), a person who was not a party to the previous litigation, and who held an unsatisfied mortgage on the franklinite in the south half, foreclosed his mortgage and obtained title thereto. He then began suit in a federal court against the New Jersey Zinc Company, and as might have been expected, the Zinc Company was beaten. The result of the litigation was that the warring interests combined and the new company became the indisputable owner of all the ores in the south half of Mine Hill and of the zinc ores in the north half. In the meantime the title to the franklinite on the north half of Mine Hill became vested in the Lehigh Zinc and Iron Company and litigation broke out again. This litigation was not carried to the higher courts so that no reports of the same are available, but Prof. J. F. Kemp, who was employed as an expert geologist in the case, states that this second litigation involved the same old question of the construction of the reservation of the franklinite in the deeds. The Zinc Company kept the litigation in the state courts of New Jersey so as to have the benefit of the above New Jersey decision that the title to the franklinite passed to the Zinc Company, but they were nevertheless beaten in the litigation and gave up the attempt to obtain the franklinite deposits by virtue of a supposed legal title and again formed a combination with the opposing company, so that the entire deposit is now owned by one corporation and the possibility of litigation extinguished.

A frequent source of mineral litigation is from disputes as to whether stone used for building purposes, etc., passes under the word mineral. Perhaps the leading case of this variety is that of Armstrong *vs.* Granite Company, 147 N. Y., 495. This was a suit which involved the construction of a deed conveying "all the mineral ores," and a second deed between the same parties to the same premises but using this time the words "minerals and ores." The dispute was as to whether these deeds gave the right to quarry and remove granite. As to the deed containing the phrase, "mineral ores," the court remarks: "It is plain the granite did not pass. The word ore has a definite signification, and designates a compound of metal and other substance. Granite neither in a popular or scientific sense is a mineral ore." The court then proceeds to discuss fully the meaning of the phrase "minerals and ores" used in the second deed, and reaches the following conclusions: "It is plain than an owner of land who grants the minerals

Digitized by Google

to another does not use the word as synonymous with mineral substances; because if this meaning was attached to the grant it would amount to a grant of the whole land, as the soil and all below it would be embraced in that description. * * * Upon the authorities, we think we should be justified in holding that the granite was not embraced in a reservation or grant of minerals in the absence of qualification. It is no doubt true that this word in its more common application in a grant of 'minerals' would be deemed to refer to metallic substances. This perhaps grows out of the fact that mining is to a great extent prosecuted for the purpose of obtaining gold, silver, iron and other metals, and grants of 'minerals' or reservations thereof in conveyances of public land are most frequently made with reference to mineral bearing ores, or metallic deposits. But it would be an unwarranted limitation of such grant or reservation to exclude from its operation beds of coal or other non-metallic mineral deposits of commercial value, or to confine it to such minerals as were known or supposed to be on the premises at the time. The grant or reservation of minerals in a deed contemplates substances to be severed and taken away from the premises, and it is difficult to suppose that the parties to such a deed intended to exclude from the grant any description of valuable mineral which would come within the legal meaning of the word, which might thereafter be discovered. We are of opinion, therefore, that the words 'minerals and ores' in the grant of 1871, standing alone, would include the granite upon the premises." However, on other provisions of the deed showing that the minerals and ores referred to were only those to be gotten by subterranean mining while the granite could only be worked by an open quarry, the court decides that in this case the deed did not pass the granite.

Another New York case that involved the same question is that of Brady *vs.* Brady, 65 N. Y. Supp., 621, here the words of the reservation were: "all mines and minerals, * * * with the right * * * to dig and carry away the same." The material in dispute was a crystalline limestone or marble and the court says: "The material, clearly, is a mineral, and it is reserved from the grant unless "the nature and context of the deed shows that it was not intended to be included in the reservation. There is nothing to justify such a finding. The only claim that can be made is that the ledges of rocks were so apparent, and covered so largely a

Digitized by Google

portion of the original 100 acres, that the parties could not have referred to them, that to except them would practically destroy the grant. Yet it may equally well be said that the knowledge that this mineral existed was the very reason that a reservation was inserted in the deed."

This same property came into litigation in the United States Court * and the United States Circuit Court of Appeals endorsed the above decision of the New York Court saying: "And, finally, the sublease of June 25, 1895, by the assignee of the term, the Oswegatchie Quarry Company, to the Metropolitan Marble Company (the plaintiff company), contained the same exception and reservation, namely 'excepting and reserving mines and minerals as specified in the original conveyance.' Since our judgment upon the former writ of error, the Supreme Court of New York, in the case Brady *vs.* Brady, 65 N. Y. Supp. 621, has held at the ownership of the marble in the tract of land conveyed by the above mentioned deed of John La Farge remained in him by virture of the exception and reservation of 'mines and minerals' contained in his deed. In so holding, the Supreme Court followed the interpretation which the Court of Appeals gave to the words 'minerals' in a grant or reservation in its opinion in the case of Armstrong *vs.* Granite Company.

In a Michigan case † on a reservation in a conveyance of all "mines and ores of metals" the court decides that "marble or serpentine" not known to exist, at the time of the conveyance did not pass as not being in contemplation of the parties at the time the deed was made but the decision might better be placed on the ground that neither marble nor serpentine is an "ore of a metal." The decision that the mineral was not included because it was not known to exist at the time the deed was made is not sound. The New York Court, cited above, and the weight of authority is against this position.

Another source of litigation involving the definition of minerals has been disputes about petroleum and natural gas. The earliest case I have found involving this question is Funk *vs.* Holdeman, 53 Pa. St., 229, decided in 1866, in which the court says: "Throughout this opinion I have treated oil as a mineral. Until our scientific knowledge on the subject is increased, this is the light in

* Phelp *vs.* Church of Our Lady, Help of Christians, 115 Fed., 882.

† The Deer Lake Company *vs.* The Michigan Land & Iron Company, 89 Mich., 180.

Digitized by Google

which the courts will be likely to regard this valuable production of the earth." But in this case classification of oil as a mineral only arose incidentally and was not necessary to the decision of the case. Also in the case of Appeal of Stoughton al 88 Pa. St., 198, the court says: "Oil, however, is a mineral and being a mineral is a part of the realty."

However, curiously, the first time the question came directly before the Pennsylvania Supreme Court in the interpretation of a reservation in a deed of "all mineral" in the case of Dunham Short *vs.* Kirkpatrick, 101 Pa. St., 36, it decided the classification of petroleum opposite to the previous case, placing the decision on the doubtful ground of the views of the "mass of mankind" adopting the words of a previous decision on another case saying: "We must, by some means, limit the meaning of the word 'minerals.'" But the rule by which this may be done is well stated by Chief Justice Gibson in the case of the Schuylkill Navigation Company *vs.* Moore, 2 Wk. 477 as follows: "The best construction is that which is made by viewing the subject of the contract as the mass of mankind would view it; for it may be safely assumed that such was the aspect in which the parties themselves viewed it. * * * Certainly in popular estimation petroleum is not regarded as a mineral substance any more than is animal or vegetable oil, and it can indeed, only be so classified in the most general or scientific sense."

However when the subject was next before the Pennsylvania Supreme Court in the case Gill *vs.* Westan, 110 Pa. St, 313, the first view was apparently again adopted for the court says referring to petroleum: "It is a mineral substance obtained from the earth by a process of mining, and lands from which it is obtained may with propriety be called mining lands."

Again in a later case, Westmoreland and Cambrian Natural Gas Company *vs.* De Witt, 130 Pa. State, the court says: "The learned master says gas is a mineral, and while *in situ* is a part of the land and therefore possession of the land is possession of the gas. But this deduction must be made with some qualification. Gas, it is true, is a mineral. * * * Water, oil, and still more strongly gas, may be classed by themselves, if the analogy be not too forceful, as minerals *feræ naturæ*. * * * They belong to the owner of the land and are a part of it, so long as they are on or in it; and are subject to his control." But if gas is a mineral, *a fortiori* is oil a mineral.

Digitized by Google

However when we examine the courts of other states we find the decisions uniformily holding oil and gas to be minerals.

In the case of Williamson *vs.* Janes, 19 S. E., 436 (W. Va.) the court says: "However the decisions in other states may have been, it has never been held in this state; and the authorities now very generally — universally so far as I have examined them — hold petroleum to be a mineral, and as much a part of the realty as timber, coal or iron ore."

In the case Murray *vs.* Allord, 100 Tenn., 100, 43 S. W., 355, the question arose as to whether petroleum and natural gas were included under the words "mines, minerals and metals," and the court elaborately reviews the theories of the origin of the substances, their composition, the technical definition of the words above, and decides that petroleum and natural gas are included in the term mineral. Consequently, it may be stated as a well settled legal principle in the United States that petroleum and natural gas are "minerals" and pass under that term when used in conveyances, contracts, etc. *

By special statutory provision, in order to prevent a monopoly of an absolute necessary article, Congress early excepted saline deposits from disposition as other mineral land and also from sale or entry or homesteading as agricultural land, and such saline lands were disposed of in a special manner designed to prevent monopolies. However, by the act of January 31, 1901, it was provided that saline lands might be located and patented under the provision of the mining laws relating to placers. This act was probably passed on the theory that by the wide discoveries of later years of immense deposits of salt in numerous parts of the country and new methods of mining the same, the danger of monopoly no longer existed.†

As to coal it is so clearly a mineral that it does not appear that any direct litigation has ever arisen as to its being included in a grant or reservation of minerals but in nearly all of the previously cited cases coal is mentioned in the decisions as being an example of a mineral that would pass under that name in a conveyance.‡

Water is a mineral and is also classified as one of the rocks. §

* Gas Company *vs.* Tyner, 131 Ind., 277; Petroleum Company *vs.* Transportation Company, 28 W. Va., 210; Thompson *vs.* Noble, 3 Pittsb., 201.

† Morton *vs.* Nebraska, 21 Wall, 660; ReSalt Bluff Placer, 7 L. D. 549.

‡ Henry *vs.* Lowe, 73 Mo. 96.

§ Grabau, On the Classification of the Sedimentary Rocks. Am. Geol., April, 1904, p. 228. Kemp, Handbook of Rocks, p. 2.

Digitized by Google

The law in relation to water and its uses as it exists on the surface of the earth in the form of stream, lakes, pond, and the ocean, forms an extensive subdivision of the law which does not properly come within the scope of this essay, but the law that relates to subterranean water may be appropriately discussed in this connection, for water in this situation is very analagous to other minerals, especially petroleum and natural gas.

When subterranean water flows in a definite stream underground the rule in relation thereto is the same as to surface streams. It cannot be entirely used or diverted by the owner of the land through which it passes. Such owner must allow the water to pass onward for the use of the land owners below subject to such reasonable and ordinary use for his own purposes as may be necessary.* But waters which come to the surface in the form of springs. etc., are presumed to be formed by ordinary percolations unless the water is affirmatively shown to flow in channels under ground.†

But where the water is percolating underground without any definite channel or in unknown channels, or is simply resting stationary in the strata as an underground pool, then the water belongs to the land under the surface of which it is found, the same as any other mineral, and the owner of the land may appropriate it wholly to his own use, even though he thereby drains the water from the wells or springs of neighboring lands.‡ One of the leading cases in relation to water is Ellis *vs.* Denison, *et al.*, 21 Barbour (N. Y.), 230, the court says: "The question involved in this controversy, whether the owner of a farm may dig a ditch to drain his land, or open and work a quarry upon it, when by doing so he intercepts one of the underground sources of a spring on his neighbor's lands. * * * In the interruption of a surface current, the injury from a diminution of the water would seem to be palpable and so far direct that it would originate a valid cause of action. * * * But it is different when

* Gould on Waters, section 281, and citations there given.

† Hanson *vs.* McCue, 42 Cal., 303; Lwett *vs.* Cutt, 50 N. H., 439; Metcalf *vs.* Nelson, 8 S. D., 87, 65 N. W., 911.

‡ Frazier *vs.* Brown, 12 O. St., 299; Chatfield *vs.* Williams, 28 Vt., 49; Gould *vs.* Eaton, 111 Cal., 639; Wadsworth *vs.* Tillottson, 15 Conn., 366; Warden *vs.* City of Springfield, 9 O. Decis., 855; Taylor *vs.* Welch, 6 Ore. 198; Cole Silver Min. Co. *vs.* Virginia Gold Hill Water Co., Fed. Cas. 2,989, 1 Sawyer, 470; Alexander *vs.* U. S., 25 Ct. Cl., 87; New Albany & S. R. Co. *vs.* Peterson, 14 Ind., 112; Chase *vs.* Silverman, 62 Me., 175.

Digitized by Google

the principal stream is partially supplied by underground currents. The owners of the surface soil are not generally aware of their existence and cannot be supposed to have voluntarily acquiesced in any appropriation of them. When they purchase they are ignorant of any obstacle to the free use of their property *ab center ad cælum* and to arrest some valuable improvement, such as digging a well or cellar, draining the land, taking valuable stones from a quarry, or leveling the ground for building or agricultural purposes, because it would cause some consequential, interference and possible irremediable damage to another, would seem to be unreasonable and unjust."

This question is frequently of great importance to mine owners, for it often happens that when they pump the water out of their mine in the course of operating it that they cause neighboring wells or springs to dry up. Such a case was that of Wheatley *vs.* Baugh, 25 Pa. St., 528. In this case the plaintiff was a tanner who had a spring on his premises, the water from which he used in his business. A copper mine was opened on an adjoining farm. To operate this, it was necessary to pump out the water which flowed into the shaft but upon doing this the tanner's spring went dry and he sued the mining company. The court says: "When the filtrations are gathered into sufficient volume to have an appreciable value, and to flow into a clearly defined channel, it is generally possible to see it and to avoid diverting it without serious detriment to the owner of the land through which it flows. But percolations spread in every direction through the earth, and it is impossible to avoid disturbing them without relinquishing the necessary enjoinment of the land. Accordingly, the law has never gone so far as to recognize in one man a right to convert another's farm to his own use, for the purposes of a filter. "Such a claim, if sustained, would amount to a total abrogation of the right of property. No man could dig a cellar, or a well, or build a house on his own land, because these operations necessarily interrupt the filtration through the earth. Nor could he cut down the forest and clear his land for the purposes of husbandry because the evaporation from his land which would be caused by exposing the soil to the sun and air would inevitably diminish to some extent the supply of water which would otherwise filter." The court then makes a lengthy review of the English cases, the French code, the Prussian code, the Civil law as well as the American decisions and concludes: "In conducting

Digitized by Google

extensive mining operations it is in general impossible to preserve the flow of the subterranean waters through the interstices in which they have usually passed, and many springs must be necessarily destroyed in order that the proprietor of valuable minerals may enjoy their own. The public interest is greatly promoted by protecting this right, and it is just that the imperfect right and lesser advantage should give place to that which is perfect, and infinitely the most beneficial to individual and the community in general."

Of course it has never been contended or held, that water passed or was reserved under the term mineral used in a grant or reservation in a deed. Like the soil, water is not ordinarily mined or extracted for commercial uses, and hence there is no reason or occasion, in the ordinary cause of business transaction, to separate the ownership of the water from that of the earth containing it and so the law (following the general course of business transactions) does not include it in a grant or reservation under the general term mineral, although the ownership of subterranean waters may be separated from the soil containing the same by a special provision of a conveyance or other legal instrument.

In England clay, both that of fine quality (kaolin) used for making chinaware and ordinary brick clay are held to be minerals in law; but in the United States, apparently no cases have come before the court involving the legal classification of clay. Metamorphosed clay or slate has exactly the same legal status as ordinary clay. In England it is held to be included under the term mineral but has not been passed upon by the courts in the United States.

We may summarize the American law as to the legal definition and meaning of the word mineral when used in deed, leases, or other legal instruments, as including, in the absence of special provisions in such instruments, all metallic minerals of sufficient value to justify mining and extracting the same whether for the purpose of reducing the metal therefrom or some other industrial use. It also includes rock used for building material, etc., coal, petroleum oil and natural gas. Kaolin, brick clay, slate, etc., have not been passed upon by the American Courts but on the authority of the English cases and the decisions of the Land Departments hereinafter mentioned, the probabilities preponderate that the courts will hold them to be included under the term mineral the same as granite, marble, etc.

Digitized by Google

Although in many of the decisions cited above the term "ores" occurs in connection with the term mineral or minerals, yet, strange to say, it has not been defined separately in any American case. Perhaps the best scientific and commercial definition that can be given of the word ore is that it is a mineral that can be profitably mined. By this definition, however, a mineral that would be included under the term ore one day might, by a fluctuation of the metal or mineral market, be excluded the next day, and it is probable that it is the recognition of the uncertain, shifting value of the term that has been the cause of its use in legal instruments only in connection with the more fixed term mineral and the reason also that the courts have devoted their attention when the question of definition arose solely to the comparatively fixed and stable term minerals.

Proceeding to the decisions under the U. S. land laws, it is first to be noted that the statutes of the United States, Sec. 2318, chapter 6, revised statutes provide "in all cases lands valuable for minerals shall be reserved from sale except as otherwise expressly provided by law, and Sec. 2319, All valuable mineral deposits in lands belonging to the United States, both surveyed and unsurveyed, are hereby declared to be free and open to exploration and purchase, and the lands in which they are found to occupations and purchase * * * ."

Under this important statute the question has often arisen as to what is a mineral and what is mineral land within the meaning of the statute.

The definition of a mineral by Commissioner Drummond of the general land office, in a general circular of July 15, 1873, has frequently been quoted since. This is: "That whatever is recognized as a mineral by a standard authority on the subject, where the same is found in quantity and quality to render the land sought to be patented more valuable on this account than for purposes of agriculture should be figured by this office as coming within the purview of the mining act of May 10, 1872." The act of 1872 referred to in this definition contains the statutory provisions quoted above, which were afterward incorporated into the revised statutes.

On most of the questions connected with the interpretation of the land laws, and particularly concerning the character of the land the decision of the land department is final, so that its interpreta-

Digitized by Google

tion have the effect of law and I present a synopsis of those that relate to minerals and mineral lands.

Land containing gold in sufficient quantities to justify men of ordinary prudence in the expenditure of money and labor in mining development must be regarded as mineral in character,* but gold in non-paying quantity will not defeat the agricultural character of the land. †

For land containing limestone to fall within the mineral laws it must affirmatively appear that it is more valuable for the limestone than for agricultural purposes. ‡

Guano is held in a decision of the land department to be a mineral. § The decision says: "Guano is the excrement of sea birds, accumulating during a long period of years into beds of varying thickness. It is a phosphate deposit, and is is classed by Dana in his System of Mineralogy among the apatite group of minerals. * * * Chemical analysis of the Gunison Island phosphate shows that its composition is substantially the same as that of the phosphate deposits of Florida. In the recent case of the Florida Central and Peninsula Railroad Company (26 L. D., 600), the department held, relative to Florida phosphate lands, that land valuable for deposits of phosphates are mineral lands within the intent and meaning of the laws relating to the disposal of the public domain. It must be said, therefore, that guano is a mineral, and that lands valuable for deposits of guano are within the meaning of the mining and other laws of the United States." The question arose in connection with certain lands on Gunison Island in the Great Salt Lake, in Utah, which have been located as placer deposits. The decision upheld the rights of the locators under the mining laws against other claimants on the grounds, stated above, that guano is a mineral.

"Under all authorities gypsum is a mineral." *

"It was early determined by the Department that the act of May 10, 1872, which describes certain land containing mineral deposits was applicable to land containing deposits of borax, carbonate and nitrate of soda, sulphur, alum and asphalt, and I believe

* 23 L. D., 34.

NOTE. — L. D. is the abbreviation for Land Decisions, a series of volumes containing the decisions of the Interior Department on questions involving public lands.

† 7 L. D., 424.

‡ 22 L. D., 353.

§ 27 L. D., 95.

Digitized by Google

that, from the passage of the law until the present time, the definition of the term 'valuable mineral deposits' has been held to include the minerals and alkaline substances."*

"Lands containing mineral springs not of a saline character, are subject to sale under the acts relating to the sale of mineral lands." †

Under the land laws of the United States petroleum has been recognized as a mineral within the meaning of such laws, both by the courts and the decisions of the Land Department. In the case of Gird *vs.* California Oil Company, 60 Fed., 531, the litigation arose in a mining district organized as an oil district, called the Little Sespe petroleum mining district. In the opinion in this case the court says: "It is undoubtedly true that petroleum, with its natural gas, unlike other mineral deposits, is movable. * * * But, as the normal condition of petroleum is one of repose and not motion, it belongs to the rock in which it is imbedded."

The leading case in the courts on the question of what constitutes mineral lands under the above cited statute is; Davis's Administrator *vs.* Weibbold, 139 U. S., 507. This was a case of a contest between holders of a mining patent and a title acquired under the town site act, and in the case the whole question of mineral lands is fully discussed by the United States Supreme, Court, the final authority in such cases. The court says: "When the entry of the town site was had, and the patent issued, and the sale was made to the defendant of the lots held by him, it was not known — at least it does not appear that it was known — that there were any valuable mineral lands within the town site, and the important question is whether in the absence of this knowledge the defendant can be deprived under the laws of the United States of the premises purchased and occupied by him because of a subsequent discovery of minerals in them and the issue of a patent to the discoverer.

After much consideration the answer must be in the negative. It is true the language of the revised statues touching the acquisition of title to mineral lands within the limits of town sites is very broad. The declaration that "no title shall be acquired" under the provisions relating to such town sites, and the sale of lands therein "to any mine of gold, silver, cinnabar or copper; or to any valid

* 1 L. D., 561.

† 1 L. D., 562, 9 Copp's Land Owner, 230.

Digitized by Google

mining claim or possession held under existing laws," would seem on first impression to constitute a reservation of such mines in the land sold, and of mining claims on them, to the United States; but such is not the necessary meaning of the terms used; in strictness they import only that the provisions by which the title to the land in such town sites is transferred shall not be the means of passing a title also to miles of gold, silver, cinnabar or copper in the land, or to valid mining claims or possessions thereon. They are to be read in connection with the clause protecting existing rights to mineral veins; and with the qualification uniformly accompanying exceptions in Acts of Congress of mineral lands from grant or sale. Thus read they must be held, we think, merely to prohibit the passage of title under the provisions of town site laws to mines of gold, silver, cinnabar or copper, which are known to exist, on the issue of the town site patent, and to mining claims and mining possessions, in respect to which such proceedings have been taken under the law or the customs of miners, as to render them valid, creating a property right in the holder, and not to prohibit the acquisition of all kinds of mines which then lay buried unknown in the depths of the earth. The exceptions of mineral land from preëmption and settlement and from grant to states for universities and schools, or the construction of public buildings, and in aid of railroads and other works of internal improvments are not held to exclude all land in which minerals may be found, but only those where the mineral is in sufficient quantity to add to their richness and to justify expenditure for its extraction, and known to be so at the date of the grant. There are vast tracts of country in the mining states which contain precious metal in small quantities, but not to a sufficient extent to justify the expense of their exploitation. It is not to such lands that the term mineral in the sense of this statute is applicable."

The only decisions of the Land Department directly on the subject, hold * that clay is not locatable as a mineral, on the ground, that being everywhere present in the soil, in greater or less quantity, to permit it to be located as mineral land, would allow all agricultural land to be located under the guise of mineral plains. It is claimed † that this decision is practically overruled by a later one of the Department.‡

* Jordon *vs.* Idaho Aluminum M. & M. Company, 20 L. D., 500.

† Snyder on Mines, Sec., 144.

‡ Pacific Coast Marble Company *vs.* Northern Pacific Ry. Company, 25 L. D., 233.

Digitized by Google

Other minerals which have been held by the decisions of the Land Department to come within the U. S. laws relating to mineral land are: albertite, gilsonite, alum, amygdaloid bands, agate, fahl-bands, garnet, graphite, lithographic stone, mica, opal, slate, tin, turquois, amber and wax.*

The United States tariff laws now in force admit "minerals, crude, or not advanced in value or condition by refining or grinding, or by other process of manufacture, not specially provided for in this act," free of duty. The minerals "specially provided for" are: "Metallic mineral substances in a crude state, and metals unwrought not specially provided for in this act, 20 percentum ad valorem; monazite sand and thorium, six cents per pound; mica, unmanufactured or rough trimmed only, six cents per pound and twenty percentum ad valorem: mica, cut or trimmed, 12 cents per pound and twenty percentum ad valorem."

Under these as well as under prior tariff laws a number of interesting questions have arisen as to what substances came within the terms of the above cited statutes and other tariff laws. One of the most interesting cases was concerning natural gas. At Buffalo natural gas was piped across the river from Canada and sold in the United States and the question arose was it a "crude mineral" or a "crude bitumen" within the meaning of the tariff laws. If so, it could be brought into the United States, free on duty, but if not it must pay ten per cent. duty. The case arose in 1891 and was carried up to the courts which finally decided that natural gas should be admitted duty free as a "crude mineral." The matter first came before the board of general appraises and in their opinion quoted *in re* Buffalo Natural Gas Fuel Company, 73 Fed., 191, they say: "The natural gas in question is similar to that produced in Pennsylvania and Ohio, but it was not imported prior to October 1, 1890. Consequently, there are no precedents to serve as guides. Nor does it appear that at or prior to the passage of the present tariff act the dutiable character of natural gas was ever considered in or out of Congress. Nor has there ever been any trade of popular designation which would indicate its proper classification for dutiable purposes. It is proper, therefore, to resort to the evidence of scientific experts and to other authorities bearing upon the question. * * * While there was conflict in the testimony, the preponderance of the evidence was to the effect that natural gas is

* Snyder on Mines, p. 117.

Digitized by Google

a crude mineral. Lexicographers and mineralogists give the word 'mineral' in its primary and broadest sense, a definition which would embrace natural gas, although their secondary and limited definition would not. * * * We find that natural gas is a crude mineral, and sustain the claim that it is exempt from duty."

When the case reached the Federal Court, this court says in the above cited decision: "The court sees no reason to disturb this decision. Indeed, it is probable that were the issue to be decided here *de novo* a similiar conclusion would be reached. * * * The decision of the board should be affirmed."

In the case of Batterson *vs.* Magone, 48 Fed., 298, the question arose in regard to Mexican onyx as to whether it was admissable free as onyx proper, which is the chalcedonic variety of quartz, or whether it was dutiable as a marble. On the trial a chemist was placed on the stand as a witness who testified that he had analyzed the rock and that its composition was:

Carbonate of lime	95.56 per cent.
Carbonate of magnesia	2.32 per cent.
Anhydrous sulphate of lime	0.13 per cent.
Ferrous and ferric oxides	1.85 per cent.
Residue	0.14 per cent.

and that it was crystalline, composed of rhombohedral crystals. Under the instructions of the court, the decisions of the case (which was a jury trial) was, that it was dutiable as a marble.

In Fisher et al. *vs.* United States, 91 Fed., 759, the question arose whether Istrian stone or marble quarried ten miles from Trieste was dutiable as marble or at a lower rate under another classification.

This is the stone of which Venice is largely built and if a marble is a coarse and cheap one but the decision of the case was that it was dutiable as marble.

In Marble *vs.* Merritt, 116 U. S., 11, the contention was whether iron ore should be classified as an unmanufactured metallic substance or under the terms, "mineral and bituminous substances in a crude state" and the decision was, very correctly, that it came under the mineral classification.

A great many contests as to the classification of minerals under the custom laws do not come before the court but are decided by the Board of Appraisers, although there is an appeal provided to the courts. But in many instances this provision is not taken

Digitized by Google

advantage of and the decision of the Board of Appraises and in some cases of the secretary of the Treasury is final. These decisions are printed in a series entitled Treasury Decisions and published by the Government, the decisions being numbered consecutively. This series is hereinafter cited T. D., and an abstract is given of the most important decision directly concerning minerals.

Articles of jade (vases, etc.) are dutiable as articles composed of mineral substances and not as precious stones.*

Ground talc or French chalk is dutiable as a mineral substance (p. 97, act '97).†

Sapphire meter jewels or compass centers are classified as mineral substances at 25 per cent. ad valorem (p. 97, act '97) and not as precious stones.‡

Imitation pumice stone and scouring bricks are dutiable as mineral substance. §

Molybdenite is dutiable as a metallic mineral substance. ‖

"Putz pomade" is dutiable as an article composed wholly or in chief part of mineral substance.¶

Gravel bought as ballast is entitled to free entry and crude mineral. **

Caen stone sweepings from a marble or a stone yard are free as crude mineral.††

Lime rock (rubble) is entitled to free entry as an unenumerated crude mineral.‡‡

Articles made of "tiger-eye" is classified as a mineral and not as a precious stone. §§

Artificial teeth are dutiable as articles of mineral substance under par. 97, act of '97. ‖‖

Electric light carbons are classified as "mineral substance." ¶¶

---

* 126 Fed., 255.
† T. D. 19,596, and 19,660.
‡ T. D. 23,727.
§ T. D. 22,682.
‖ T. D. 18,849.
¶ T. D. 20,287.
** T. D. 25,627.
†† T. D. 24,988.
‡‡ T. D. 16,172.
§§ T. D. 25,083.
‖‖ T. D. 22,350.
¶¶ T. D. 20,579. C. C. A. N. Y., Dec. 12, '98.

Digitized by Google

Actinolite is dutiable at twenty per cent. ad valorem and is not the same as asbestos.*

Apatite is free under the act of 1895, p. 500, for use as manure.†

Siliceous stone is a mineral substance and when ground is "advanced in value or condition" and dutiable, and not free as sand.‡

Cornish stone was found to be a variety of feldspar and held not dutiable, being a crude mineral.§

Talc is non-dutiable as a crude mineral and does not come under the classification of French chalk.‖

Earth composed of oxide of iron, silica, alumina, and lime used as a polishing powder is dutiable as an "earth manufactured" at $3.00 per ton.¶

Asphaltum is non-dutiable coming under the classification of a crude mineral.**

Under the last subdivision of this subject no further summary is possible than the enumeration and digest of the decisions given herein; for each decision being the interpretation by a court or other proper authority as to what is included under the term mineral, mineral load, crude mineral, etc., as used in the statutes cited, the case of each particular substance must be decided by the facts relating to such substance so that the precedent of the case does not go farther than the substance passed upon or those so similar as to be practically identical. It may be noted, however, that in all the subdivisions of the subject that the cases show an increasing tendency of the courts and other authorities to call for and rely on the expert testimony of scientific men, — chemists, engineers and geologists for aid in deciding the important cases that arise under this subject. As the quotations given above from the early cases indicate, there then existed a marked tendency in the courts to make some supposed understanding of the "mass of mankind" the basis of decisions on these questions, usually with unsatisfactory results, while those decisions arrived at by the aid of competent scientific testimony have stood and become reliable precedents.

*T. D. 16,013.
†T. D. 16,097.
‡T. D. 15,701 (1895).
§T. D. 11,240 (1891).
‖T. D. 12,240 (1892).
¶T. D. 10,784.
**T. D. 12,817.

Digitized by Google

THE EFFECT OF VARIATIONS IN THE SPEED OF CRUSHING MACHINERY UPON THE PRODUCTION OF UNDERSIZED MATERIAL.*

By H. W. GARTRELL.

The proper speed at which a crusher should be run is of obvious importance, since it directly governs the output, and large output being one of the chief objects in many mills there is a tendency to run crushers at higher speeds than formerly. This is especially the case with rolls, the speed of the old Cornish rolls having been multiplied many times in modern design. Various points however need consideration, for instance one mill in this country changed the speed of a pair of rolls from 102 to 92 revolutions, to overcome excessive wear of the cast steel faces, while another in crushing a limestone galena changed from 35 to 28 revolutions to prevent glazing. The object of this investigation was to follow up another line, that of the production of undersized material, which is responsible for so large a proportion of the losses of many mills. There seems to be a general impression that high speeds give an undue proportion of such material, though the authorities are almost entirely silent on the subject. The writer has not been able to find any published investigations on this point, though he believes that in the case of coal crushing by toothed rolls, some unpublished tests fully confirm the idea.

In the case of ores it is not sufficient to know the amount of undersized material produced, but also to gain some idea of the effect on the economic minerals present, for it is in these that the losses occur. A tough galena-blende ore was selected, the gangue being siliceous with large quantities of feldspar, and an attempt was made to judge the effect on the galena by vanning the material passing a 16 mm. screen. The results, however, were so irregular that a second investigation was conducted on a sample of carefully cobbed galena, which from the very high proportion of brittle mineral would show any variations of importance. The machines used were a Krom jaw crusher, 5″ by 12″, of the type shown on p. 32 of the catalogue of '97 to '98; a style F, third pattern, Gates crusher and a pair of 16″ Krom Rolls designed to run at 100 and 101 revolutions. Of

* Submitted in partial fulfillment of major subject for degree of Master of Arts, in the School of Mines, Columbia University.

Digitized by Google

these the gyratory is naturally very much smaller than would be used in practice, but the other machines are large enough for commercial use. The products were screened in a series of screens approximating Rittinger's scale, and ranging from 44 mm. to .16 mm., the work being done wet below 2.5 mm. All the holes were square and the measurements given are the mean linear apertures. After the coarser sizes had been removed a split sampler and riffles were used to diminish the quantity handled, the principle observed being that the aperture of the sampler should be at least four times the diameter of the largest particle.

The speeds of jaw crusher used ranged from 73 to 520 revolutions per minute for the ore, and 70 to 537 revolutions for the galena. As American practice, Richards quotes 59 breakers of the Blake type ranging from 84 to 500 revolutions with a mean of 252. It may be noted that only one machine, a 6″ by 8″, ran at 500 revolutions, and two, an 8″ by 10″ and a 6″ by 9″ at 400 revolutions, suggesting that the reason for these exceptional speeds was a necessity for maximum capacity. Five breakers of the Dodge type ranged from 190 to 366 revolutions, with a mean of 254. For spindle-breakers the same authority quotes pulley revolutions of 320 to 500 with a mean of 402, and catalogue speeds of 350 to 700, the last figure however being for a laboratory crusher. In these

SCREEN-CLASSIFICATION OF ORE CRUSHED IN JAW CRUSHER.

Mean Screen Aperture in Millimeters.	Per Cent.				Cumulative Per Cent.			
	520 Revs. per Min	407 Revs. per Min.	285 Revs. per Min.	73 Revs. per Min.	520 Revs. per Min.	407 Revs. per Min.	285 Revs. per Min.	73 Revs. per Min.
44	.8	2.1	1.8	2.4	.8	2.1	1.8	2.4
32	17.5	15.5	20.1	24.9	18.3	17.6	21.9	27.3
21	34.7	35.7	34.6	30.9	53.0	53.3	56.5	58.2
15.2	16.8	16.7	14.5	14.8	69.8	70.0	71.0	73.0
10.3	10.2	9.9	10.8	10.5	80.0	79.9	81.8	83.5
6.7	5.3	5.7	4.8	4.4	85.3	85.6	86.6	87.9
5.2	2.2	2.1	1.9	2.1	87.5	87.7	88.5	90.0
4.0	2.0	1.6	1.8	1.5	89.5	89.3	90.3	91.5
3.46	.9	.9	.8	.8	90.4	90.2	91.1	92.3
2.58	1.7	1.7	1.5	1.5	92.1	91.9	92.6	93.8
1.50	1.9	2.0	1.8	1.4	94.0	93.9	94.4	95.2
1.05	1.2	1.2	1.0	.9	95.2	95.1	95.4	96.1
.71	.8	.8	.8	.7	96.0	95.9	96.2	96.8
.51	.8	.7	.7	.6	96.8	96.6	96.9	97.4
.16	1.5	1.5	1.4	1.2	98.3	98.1	98.3	98.6
< .16	1.7	1.9	1.7	1.4	100.0	100.0	100.0	100.0
Weight of ore in pounds.	284	354	248	297	284	354	248	297

Digitized by Google

experiments the extremes were 136 and 980 revolutions and 141 and 1,004 for ore and galena respectively. Finally 71 rolls are quoted as ranging from 8.5 to 130 revolutions with a mean of 53, though

SCREEN-CLASSIFICATION OF ORE CRUSHED IN ROLLS.

Mean Screen Aperture in Millimeters.	Per Cent.				Cumulative Per Cent			
	145 Revs. per Min.	115 Revs. per Min.	85 Revs per Min.	20 Revs. per Min.	145 Revs. per Min.	115 Revs. per Min.	85 Revs. per Min.	20 Revs. per Min.
10.3	1.3	1.6	1.0	2.0	1.3	1.6	1.0	2.0
6.7	9.2	10.6	9.8	12.2	10.5	12.2	10.8	14.2
5.2	13.3	10.2	15.6	13.5	23.8	22.4	26.4	27.7
4.0	13.3	13.3	17.0	18.7	37.1	35.7	43.4	46.4
3.46	11.2	15.1	8.8	8.2	48.3	50.8	52.2	54.6
2.58	14.7	13.7	13.9	13.5	63.0	64.5	66.1	68.1
1.50	12.0	13.0	12.2	10.9	75.0	77.5	78.3	79.0
1.05	6.2	5.7	5.2	5.0	81.2	83.2	83.5	84.0
.71	3.8	3.5	3.2	3.1	85.0	86.7	86.7	87.1
.51	3.3	3.0	2.7	2.5	88.3	89.7	89.4	89.6
.16	6.3	5.6	5.4	5.2	94.6	95.3	94.8	94.8
< .16	5.4	4.7	5.2	5.2	100.0	100.0	100.0	100.0
Weight of ore in pounds.	138	158	104	141	138	158	104	141
Peripheral speed, in feet per minute.	610	480	355	85	610	480	355	85

recent catalogues give 50 to 180, while 20 to 145 and 20 to 143 were the limits used here.

SCREEN-CLASSIFICATION OF ORE CRUSHED IN GYRATORY CRUSHER.

Mean Screen Aperture in Millimeters.	Per Cent.				Cumulative Per Cent.			
	980 Revs. per Min.	740 Revs. per Min.	538 Revs. per Min.	136 Revs. per Min.	980 Revs. per Min.	740 Revs. per Min.	538 Revs. per Min.	136 Revs. per Min.
10.3	3.2	3.5	3.9	4.4	3.2	3.5	3.9	4.4
6.7	23.7	24.0	24.8	24.5	26.9	27.5	28.7	28.9
5.2	16.8	18.2	17.3	17.6	43.7	45.7	46.0	46.5
4.0	15.2	12.9	13.5	15.2	58.9	58.6	59.5	61.7
3.46	5.8	5.9	5.2	4.6	64.7	64.5	64.7	66.3
2.58	9 4	9.4	9.5	8.5	74.1	73.9	74.2	74.8
1.50	8.0	7.9	8.3	8.1	82.1	81.8	82.5	82.9
1.05	4.0	4.3	3.9	3.9	86.1	86.1	86.4	86.8
.71	2.6	2.6	2.5	2.6	88.7	88.7	88.9	89.4
.51	2.3	2.4	2.3	2.6	91.0	91.1	91.2	91.6
.16	4.4	4.4	4.3	4.1	95.4	95.5	95.5	95.7
< .16	4.6	4.5	4.5	4.3	100.0	100.0	100.0	100.0
Weight of ore in pounds.	96	117	80	90	96	117	80	90

This series of experiments then may be taken as including all normal practice, and in most cases reaching well beyond the limits.

Digitized by Google

The results are shown in the tables, and plotted in the curves, the ordinates being cumulative percentages, *i. e.*, the total percentage unable to pass a given sieve, and the abscissæ being proportional

SCREEN-CLASSIFICATION OF PREPARED GALENA CRUSHED IN JAW CRUSHER.

Mean Screen Aperature in Millimeters.	Per Cent.				Cumulative Per Cent.			
	537 Revs. per Min.	328 Revs. per Min.	298 Revs. per Min	70 Revs. per Min.	537 Revs. per Min.	328 Revs. per Min.	298 Revs. per Min.	70 Revs. per Min.
32	19.3	14.8	20.0	22.5	19.3	14.8	20.0	22.5
21.4	32.5	34.3	35.1	33.8	51.8	49.1	55.1	56.3
15.2	15.5	18.4	17.9	15.7	67.3	67.5	73.0	72.0
10.3	9.6	10.6	9.4	8.7	76.9	78.1	82.1	80.7
6.7	5.1	4.5	3.6	4.2	82.0	82.6	86.0	84.9
5.2	2.2	2.2	1.8	1.8	84.2	84.8	87.8	86.7
4.0	1.7	1.8	1.3	1.9	85.9	86.6	89.1	88.6
3.46	1.1	.9	1.0	.7	87.0	87.5	90.1	89.3
2.58	1.9	1.8	1.5	1.5	88.9	89.3	91.6	90.8
1.50	2.2	2.1	1.7	1.9	91.1	91.4	93.3	92.7
1.05	1.6	1.5	1.3	1.4	92.7	92.9	94.6	94.1
.71	1.3	1.2	1.0	1.0	94.0	94.1	95.6	95.1
.51	1.3	1.2	.9	1.0	95.3	95.3	96.5	96.1
.16	2.6	2.5	1.9	2.2	97.9	97.8	98.4	98.3
< .16	2.1	2.2	1.6	1.7	100.0	100.0	100.0	100.0
Weight taken in pounds.	151	149	147	148	151	149	147	148

to the logarithms of the sieve apertures. The reason logarithmic proportion was preferred to direct proportion, is the difficulty of representing on a diagram, a range of .16 mm .to 44 mm. Further,

SCREEN-CLASSIFICATION OF PREPARED GALENA CRUSHED IN ROLLS.

Mean Screen Aperture in Millimeters.	Per Cent.				Cumulative Per Cent.			
	143 Revs. per Min.	110–100 Revs. per Min.	87 Revs. per Min.	23–20 Revs. per Min.	143 Revs. per Min.	110–100 Revs. per Min.	87 Revs. per Min.	23–20 Revs. per Min.
10.3	.2	.3	.1	.5	.2	.3	.1	.5
6.7	1.1	1.4	1.3	2.1	1.3	1.7	1.4	2.6
5.2	4.0	4.3	5.4	4.6	5.3	6.0	6.8	7.2
4.0	7.1	9.7	7.2	11.8	12.4	15.7	14.0	19.0
3.46	9.7	7.0	10.0	7.2	22.1	22.7	24.0	26.2
2.58	15.1	14.9	14.6	11.8	37.2	37.6	38.6	38.0
1.50	15.0	14.2	14.4	14.4	52.2	51.8	53.0	52.4
1.05	9.1	8.3	8.5	7.8	61.3	60.1	61.5	60.2
.71	6.5	6.1	5.7	6.0	67.8	66.2	67.2	66.2
.51	6.0	6.1	5 9	5.9	73.8	72.3	73.1	72.1
.16	13.7	14.1	13.4	13.8	87.5	86.4	86.5	85.9
< .16	12.5	13.6	13.5	14.1	100.0	100.0	100.0	100.0
Weight taken in pounds.	52	52	49	42	52	52	49	42
Peripheral speed, in feet per minute.	600	460 420	365	95 85	600	460 420	365	95 85

Digitized by Google

logarithmic plotting prevents the lower part of the curves from being unduly drawn out, and this is the least important region, since it represents the oversize, or abnormally flat pieces, whose distribution is largely accidental, though the amount is fairly uniform. In the upper parts of the curves, several cases of change of curvature are made visible by the large scale employed. These are not due to accidental causes, as are those at the lower end, but to defective analysis, which is, indeed, inevitable, since the amount left on any screen in the small sizes is, to some extent a compromise, particularly in the case of the galena; for to shake long enough to get everything possible through involves production of undersize by

SCREEN-CLASSIFICATION OF PREPARED GALENA CRUSHED IN GYRATORY CRUSHER.

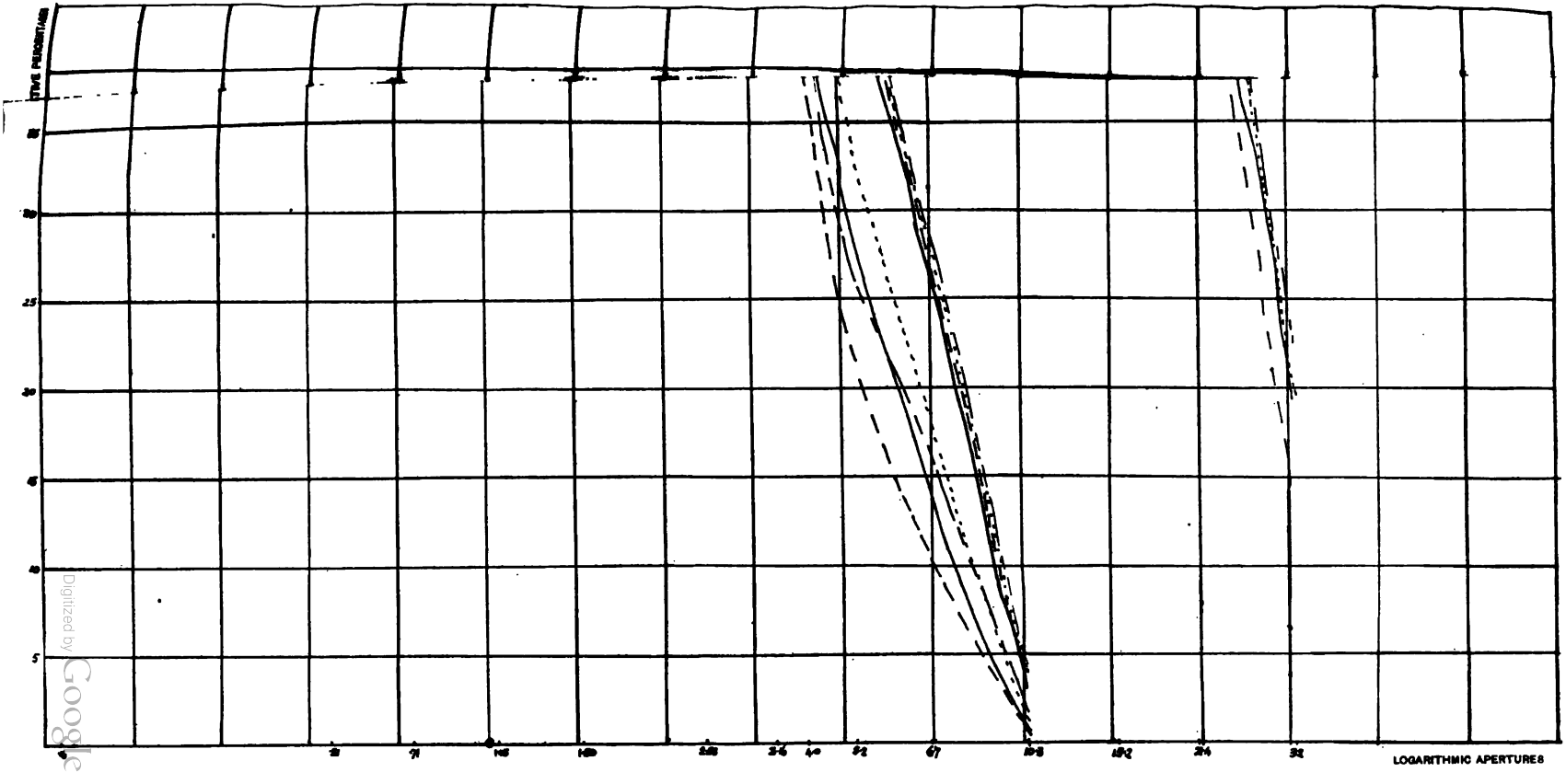
Mean Screen Aperture in Millimeters.	Per Cent.				Cumulative Per Cent.			
	1004 Revs. per Min.	660* Revs. per Min.	540 Revs per Min.	141* Revs. per Min.	1004 Revs. per Min.	660* Revs. per Min.	540 Revs. per Min.	141* Revs. per Min.
10.3	.6	.6	1.4	1.9	.6	.6	1.4	1.9
6.7	14.1	10.3	17.6	15.0	14.7	10.9	19.0	16.9
5.2	13.6	10.8	14.3	9.2	28.3	21.7	33.3	26.1
4.0	13.0	16.0	12.5	15.9	41.3	37.7	45.8	42.0
3.46	9.2	5.7	7.2	5.2	50.5	43.4	53.0	47.2
2.58	9.6	11.3	9.6	11.4	60.1	54.7	62.6	58.6
1.50	10.0	11.4	8.6	9.8	70.1	66.1	71.2	68.4
1.05	6.3	6.5	5.3	6.0	76.4	72.6	76.5	74.4
.71	4.2	4.5	3.8	4.3	80.6	77.1	80.3	78.7
.51	4.4	4.6	3.9	4.1	85.0	81.7	84.2	82.8
.16	8.3	9.6	8.6	9.2	93.3	91.3	92.8	92.0
< .16	6.7	8.7	7.2	8 0	100.0	100.0	100.0	100.0
Weight taken in pounds.	47	51	46	49	47	51	46	49

* The tests asterisked were made after changing the gyratory cone.

attrition. It is, however, worthy of note that these experimental errors are almost of the same order of magnitude as the changes with varying speed. It should be remarked that there is a discontinuity in the results of the gyratory crushing of galena, owing to the changing of a cone, so that instead of a series of four curves we have two groups of two.

The material was prepared as follows: The ore having been spalled small enough to be taken by the jaw crusher was piled in a heap, and four barrels were filled by putting a shovelful into each in turn, none of the material being fine enough to pass a 2½″ ring and the great majority very much coarser. The material from the jaw crusher lying between 32 and 21.4 mm. was used in the gyra-

Digitized by Google



Digitized by Google

Digitized by Google

tory, and the material obtained between 21.4 and 5.2 mm. used in the rolls, the object of this feeding of sized material being to make, so far as possible, the speed the only variable in the experiments. With the galena the sizing was confined within even closer limits, 63 to 32 mm., 32 to 21.4 mm., and 21.4 to 15.2 mm. for the three machines respectively.

The results obtained seem to admit of only one interpretation; that while decrease of speed tends to decrease the production of undersized material, it only does so in a degree so small that in general it is altogether disproportionate to the disadvantage of decreased capacity. Moreover the range both in speeds and in tenacity of material were sufficiently great to render it probable that similar results would be obtained under almost all conditions.

INTERNAL STRESSES IN MASONRY DAMS.

By S. D. BLEICH.

In the usual design of masonry dams and retaining walls, the only internal stresses which are considered are the direct compressive stresses on horizontal sections. The effect of shear from the horizontal forces acting against the wall is taken into account in a very elementary and approximate manner. It is thought, that if the following three conditions of stability are satisfied, the wall is safe. These are:

1. The maximum compressive stress due to the vertical forces must not exceed the safe limit for the material composing the wall.

2. No tension shall exist at any point of a section. This requires that the line of pressure must not pass outside the middle third.

3. The resistance to sliding at any horizontal section shall be greater than the total horizontal force at this section. This requires that the line of pressure must never make with the normal at any horizontal joint an angle greater than the angle of repose.

A fourth condition of stability is frequently stated, that the wall shall be safe against overturning. But when condition (2) is satisfied, there can possibly be no overturning.

Many elaborate analyses have been made for walls of straight and curved profiles. But all of them with the exception of some

Digitized by Google

few made very recently, pass over the question of the distribution of shear along horizontal and vertical planes. Solutions have been made which take account of this aspect of the problem; but most of these employ partial differential equations. A closely approximate solution of these equations from known boundary conditions can always be made; but the labor involved is appalling.

As this phase of the problem has been almost completely ignored

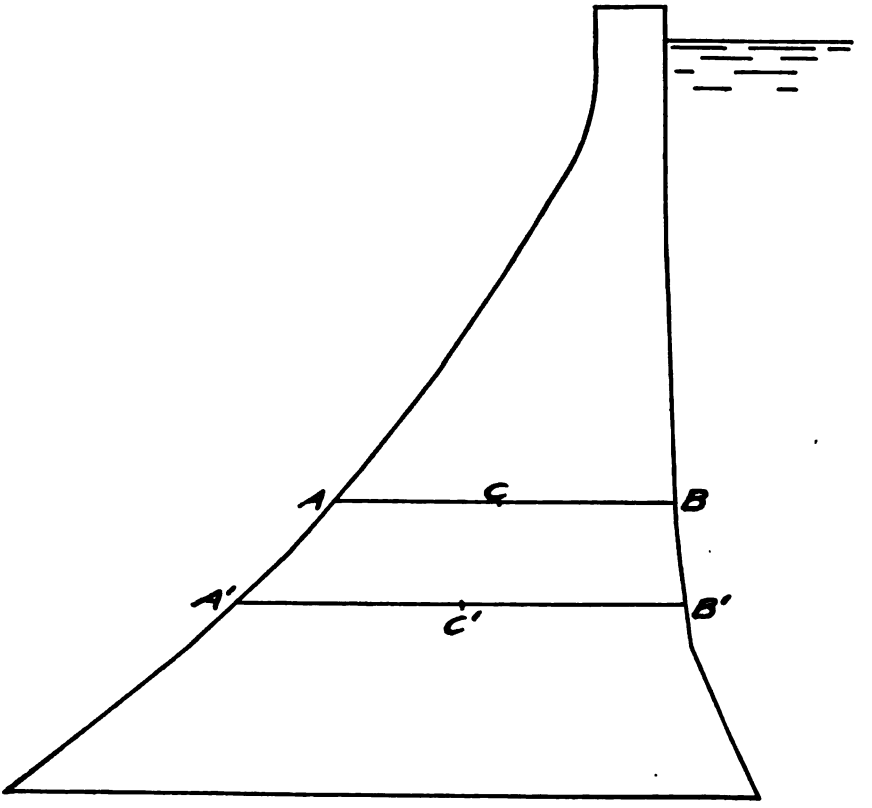


Figure 1

in both engineering books and schools, many of my fellow engineers would welcome an elucidation of this problem. It is the purpose of this paper to go into this subject as briefly as is consistent with lucidity.

Although the treatment given can be applied to all walls, whether they serve to retain water, earth, coal, etc., only such walls which

Digitized by Google

retain water will be considered as illustrative of all the others. The external forces acting on the dam are the pressure of the water, which acts normal to the line of contact between the water and the wall, the action of waves and ice, the weight of the wall, and the reaction. As the back of the wall or dam is generally very nearly vertical, the pressure of the water may be taken without any appreciable error as horizontal in direction, and the only downward vertical force considered will be that of the weight of the wall itself.

In what follows, a length of one foot of dam will be taken. In Fig. 1 consider the horizontal section AB. Let C be the center of AB. Let M equal the bending moment of the water pressure and the weight of the wall taken about C as the center of moments; and let W be the weight of the wall above AB. If σ represent the unit compressive stress at any point at a distance y from C, and if I represent the moment of inertia of the section AB about C as an axis, then

$$\sigma = \frac{M}{I} y + \frac{W}{b} = \frac{12My}{b^3} + \frac{W}{b} \qquad (1)$$

in which $AB = b$; $I = b^3/12$; and y is positive between C and A and negative between C and B.

A similar equation may be written for the section $A'B'$ by placing σ' for σ, M' for M, etc.

$$\sigma' = \frac{12M'y}{b'^3} + \frac{W'}{b'} \qquad (2)$$

Let the portion $ABB'A'$ be isolated from the wall (see Fig. 2). It will be held in equilibrium by the downward pressure and horizontal shear on AB, the upward pressure and horizontal shear against $A'B'$, the weight of $ABB'A'$, and the pressure of water against BB'. The distribution of pressure along AB is shown by $AEFB$; the equation of the line EF is given by (1). The distribution of pressure along $A'B'$ is shown by $A'E'F'B'$; the equation of $E'F'$ is given by (2). Let the stress diagrams $AEFB$ and $A'E'F'B'$ be drawn to such a scale that a unit vertical length of these diagrams of the same linear scale as the profile $ABB'A'$ will equal the weight of a cubic unit of masonry of the wall.

Consider the stress along any vertical section HH'. Remove the portion to the left of HH'. Then the total shear along HH' equals the area of the stress diagram $HGFB$ plus the weight of

Digitized by Google

$HBB'H'$ minus the area of the stress diagram $H'B'F'G'$. The total normal pressure against HH' equals the pressure of the water over a depth of HH'; and the distribution of this normal pressure will vary as the water pressure varies, directly with the depth from the free surface of the water. If HH' is taken as very small, the distribution of the shearing and normal stresses along it will be practically uniform. If we, therefore, divide the total shear by

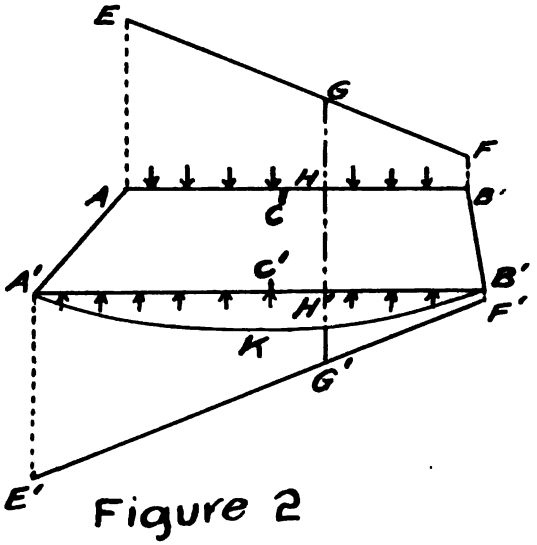


Figure 2

HH', the intensity of shear will be obtained. A similar remark applies for the intensity of pressure for HH'.

In the theory of elasticity the law is established, that the intensity of shear is equal on all four edges of an elementary rectangular figure. Consequently, whatever intensity of shear will be obtained for HH', there will be the same intensity of shear along AB or $A'B'$ at the points H or H'. Now as the intensity of shear for HH' will vary with its position, it is evident that the intensity of shear along $A'B'$ will vary at different points. From Fig. 2, it is seen that when HH' is at B', the total shear and, therefore, the intensity of shear approaches zero by an infinitesimal quantity. This is also true when HH' is at A'. Somewhere between A' and B' the intensity of shear reaches its maximum. We would, therefore, suspect that the curve giving the intensity of shear along $A'B'$ would be somewhat like $A'KB'$, and a similar curve for AB.

To obtain the shear diagram $A'KB'$, either a purely analytical

Digitized by Google

method or a combined analytical and graphical method may be pursued. In the analytical method M and W would be obtained in terms of h, the height of the wall to the horizontal section in question. These quantities would then be substituted in equation (1).

The total compressive stress on the section AB between A and a point at a distance y from C is

$$\int_y^{b/2} \sigma dy = \frac{6M}{b^3}\left(\frac{b^2}{4} - y^2\right) + \frac{W}{b}\left(\frac{b}{2} - y\right), \qquad (3)$$

in which b equals the width AB. To apply a test to this formula, put $y = -b/2$ then

$$\int_{-b/2}^{+b/2} \sigma dy = W,$$

which it should be. For the section $A'B'$, the total compressive stress between A' and a point at a distance y from C' is

$$\int_y^{b/2} \sigma' dy = \frac{6M'}{b'^3}\left(\frac{b'^2}{4} - y^2\right) + \frac{W'}{b'}\left(\frac{b'}{2} - y\right), \qquad (4)$$

in which b' is the width $A'B'$. If HH' is indefinitely reduced, then

$$HH' = dh; \quad M' = M + dM; \quad W' = W + dW,$$

b' may be taken equal to b. The weight of $AHH'A'$ equals $w'(b/2 - y)dh$ in which w' is the weight of a cubic unit of masonry in the dam. Making the above substitutions in equation (4), and subtracting from it equation (3), and then subtracting $w'(b/2 - y)dh$, we obtain the total shear along HH'. Dividing this result by dh, the intensity of shear s at the point H is obtained:

$$s = \frac{6}{b^3}\left(\frac{b^2}{4} - y^2\right)\frac{dM}{dh} + \frac{1}{b}\left(\frac{b}{2} - y\right)\frac{dW}{dh} - w'\left(\frac{b}{2} - y\right).$$

But

$$\frac{dM}{dh} = H \quad \text{and} \quad \frac{dW}{dh} = w'\left(\frac{b}{2} - y\right)$$

in which H is the total shear along AB or the pressure of water. By making the substitutions, the above equation becomes

$$s = \frac{6H}{b^3}\left(\frac{b^2}{4} - y^2\right). \qquad (5)$$

The intensity of shear varies according to a parabolic curve. When

$$y = \pm\frac{b}{2}, \quad s = 0.$$

Digitized by Google

The intensity of shear is, therefore, zero at A and B. It is a maximum for $y = 0$ or at the center of AB.

$$s_{max} = \frac{3H}{2b} \qquad (6)$$

or the maximum intensity of shear is times the average along AB. The total shear is

$$\tfrac{2}{3}bs_{max} = H$$

which it should be. For a depth of water of h' units $H = \frac{1}{2}wh'^2$, in which w is the weight of a cubic unit of water. Substituting this value for H in equation (6), there results

$$s_{max} = \tfrac{3}{4} \cdot \frac{wh'^2}{b}.$$

In the above, we have outlined the method to obtain the unit compressive stress and the unit shearing stress for any point of a horizontal section AB and also for the vertical section HH'. From these quantities, the maximum compressive stresses and shear-

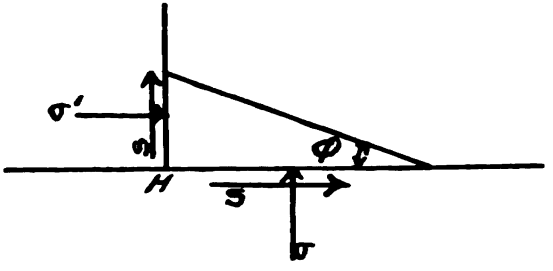


Figure 3

ing stresses and the direction of these stresses may be computed from equations established in the theory of elasticity. In Fig. 3 σ and σ' denote unit compressive stresses and s the unit shearing stress. The direction of action of these stresses is clearly shown in the figure. The method of computing these stresses has already been given. The maximum compressive stress is given by the equation

$$\sigma_{max} = \frac{\sigma + \sigma'}{2} + \tfrac{1}{2}\sqrt{4s^2 + (\sigma - \sigma')^2},$$

Digitized by Google

and the minimum stress by the equation

$$\sigma_{\min} = \frac{\sigma + \sigma'}{2} - \tfrac{1}{2}\sqrt{4s^2 + (\sigma - \sigma')^2}.$$

These stresses are known as the principal stresses. The planes on which they act are known as the principal planes, as there are no tangential stresses along these planes. The direction of these planes is given by the equation

$$\tan 2\varphi = \frac{2s}{\sigma' - \sigma}.$$

The maximum and minimum tangential shear are given by the equation

$$S_{\substack{\max \\ \min}} = \pm \tfrac{1}{2}\sqrt{4s^2 + (\sigma - \sigma')^2}.$$

The planes along which they act are given by the equation

$$\tan 2\varphi = \frac{\sigma - \sigma'}{2s}.$$

THE CONSTITUTION OF QUININE.*

BY BENJAMIN LINDLEY MURRAY.

Somewhat more than two hundred and fifty years ago, in 1638 to be exact, a certain Vice-Queen of Peru was cured of fever by the use of the bark of some trees native of Peru. After her recovery this grateful woman, the Countess of Cinchon, took steps to make known to the world the healing properties of the bark. In Europe, particularly in Spain, the bark now known as the wonderful Cinchona bark in honor of the Countess, came gradually into use as a febrifuge. And as we now think of quinine its most important medicinal constituent, with its wonderful antiseptic, tonic and febrifugal properties, is it strange that before very many years after its first use the supply of trees was found nearly exhausted?

It was only natural that physicians and others of an inquiring turn of mind should investigate a remedy of such sovereign worth, and so we find that, after many years of experimenting and investigating, it became possible to separate from the bark that intensely

* Contributions from the Havemeyer Laboratories of Columbia University, No. 115.

Digitized by Google

bitter portion that gives it healing power. Indeed it required nearly two hundred years of use to teach us the presence and nature of the alkaloids in cinchona bark. It was at a comparatively recent date, therefore, 1820, that two investigators, working together, succeeded in isolating two pure alkaloids. From an extract which they had made both cinchonine and quinine were obtained in pure condition. To Pelletier and Caventou belongs the honor of discovering quinine (1, 2).*

Of the twenty-one alkaloids that have thus far been discovered in cinchona bark, without hesitation quinine is selected as the most important.

Let us inquire for a moment why this is. Primarily it is on account of its peculiar and unique therapeutic action. Quinine is considered in the medical profession as almost, if not quite, a specific for fevers of a malarial nature. And we should remember that in all our extensive materia medica there are indeed few specifics.

We are not particularly concerned in this paper with the exact modus operandi by which our alkaloid overcomes the pernicious effects of the parasites causing intermittent fevers; but one theory advanced to explain its action is interesting. It is suggested that quinine is of such a composition as to combine chemically with certain constituents in the make-up of the parasitic organism, the result being the death of the organism.

A second reason for the important place won by quinine is that it predominates over the accompanying related alkaloids in point of quantity present in the bark. Cinchonine, cinchonidine, and quinidine, which are present in cinchona bark in smaller amounts, are not without effect in intermittent fevers; but fortunately quinine is the most plentiful and at the same time the most effective.

It is somewhat strange, in view of the importance of quinine and the relative unimportance of cinchonine, that we find the composition and chemical structure of quinine less thoroughly investigated than that of cinchonine. Indeed the structure of cinchonine has been worked out with much pains and several graphic formulæ have been proposed for it. Much has been done on quinine as well, although it is apt to be more lightly passed over as "similar to cinchonine," or "probably a paramethoxycinchonine."

In 1838 Liebig proposed the formula, $C_{10}H_{12}NO$ for the anhy-

* These numbers refer to the Chronological Bibliography at the close of the article.

Digitized by Google

drous alkaloid quinine (4, 6). Later, in 1854, Strecker (8, 9), and also Regnault (5) established its correct formula, $C_{20}H_{24}N_2O_2$ (3). There are no successful efforts to further establish or change the formula recorded immediately after 1854; and only minor points of the constitution were investigated at this time. Now and then for twenty years we find various reactions of quinine noted, but the period from 1878 to the present time covers the greater part of the investigations and nearly all of the important ones.

Quinine may be prepared (14) either amorphous or crystalline, the amorphous being anhydrous and readily changing to the crystalline form with three molecules of water. Anhydrous crystals are also known. Quinine solutions are lævorotary, have an alkaline reaction, a bitter taste, and with ammonia and chlorine water give a characteristic green color; dilute aqueous solutions of its salts, especially of the sulphate, show a blue fluorescence.

The anhydrous amorphous alkaloid has a melting point of 172.8° C., the anhydrous crystals 174.4–175° C., but the trihydrated base melts much lower, at 57° C. Alkalies precipitate the alkaloid from the solutions of its salts, and this property is made use of in its commercial production. The powdered cinchona bark is treated with water and alkali, generally lime, and the free bases, including quinine, are then extracted by means of suitable solvents. Various methods of separating quinine from the other alkaloids are resorted to. It is prepared synthetically by methylation of cupreine (42, 43).

Quinine is soluble in alcohol, ether, and chloroform, but quite insoluble in benzene and water, although imparting its taste to the latter. Indeed the extremely bitter taste of the alkaloid and its salts is one of the most serious drawbacks to its use in medicine. Many attempts have been made to prepare a tasteless quinine compound, or even one with a less disagreeable taste. These necessarily take the form of insoluble compounds. They are, of course, tasteless if insoluble; but, if really insoluble, they are practically inert therapeutically. The demand for tasteless quinine is so pronounced that many fraudulent preparations have been put forth from time to time, some of them free from quinine, as well as from its bitter taste. The tannate, being insoluble, is nearly tasteless. Quinine carbonic ester, with formula given as $C_{20}H_{22}N_2O_2 \cdot COOC_2H_5$, is also practically tasteless. It is dissolved by dilute alkalies, and hence in the alkaline juices of the intestinal tract it

Digitized by Google

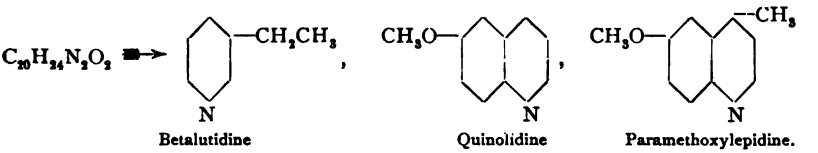
becomes therapeutically available. It is of considerable commercial importance, being especially useful for child medication.

There are several compounds known to literature that are isomeric with the alkaloid (19); and there are also several ways of producing the different isomers. Skraup and others (44, 45, 46, 52, 55, 56) after adding a molecule of a halogen acid, remove the elements of the same acid by means of alkalies; but they recover only a small per cent. of the original quinine. Instead, isoquinine, pseudoquinine, niquine, etc., are obtained. Sulphuric acid or even heat alone converts quinine into its isomers. Thus it was that Pasteur in 1853 produced quinicine, another isomer, by heating the alkaloid to 120° C. in the presence of dilute sulphuric acid (7). It may also be produced by heating with glycerol to 180° C. Skraup, Hesse, and others have studied the isomers and some of their decomposition products (44, 45, 46, 52, 55, 56).

When quinine is treated with bromine or chlorine in the cold, it takes up two atoms of the halogen. An addition product is formed. One molecule of halogen acid is added in a similar manner (39, 44, 51); and these new compounds will add two more molecules of the same or a different (44, 45, 54) halogen acid. A condition of unsaturation, therefore, exists in the alkaloid. We may further prove this by treating it with zinc and sulphuric or hydrochloric acid, when dihydroquinine, $C_{20}H_{26}N_2O_2$, is produced (13). Or, using sodium and alcohol, especially amyl alcohol and heat, tetrahydroquinine, $C_{20}H_{28}N_2O_2$, results (64, 66, 68). Very many other addition compounds have been prepared (30, 50), as for instance, the monomethiodide (47), ethiodide and ethchloride (9), the dialkyliodides (31, 42, 48, 53), ethiodide hydriodide, $C_{20}H_{24}N_2O_2 \cdot HI \cdot C_2H_5I$ (60), quinine chloral $C_{20}H_{24}N_2O_2 \cdot CCl_3CHO$ (34), quinine mono- and dichlorhydoacetates $C_{20}H_{24}N_2O_2 \cdot CH\,ClCOOH \cdot 2\frac{1}{2}H_2O$ (36), quinine nitrobenzaldehyde, $C_{20}H_{24}N_2O \cdot C_6H_4(NO_2)CHO$ (35), etc. Jobst and Hesse have also prepared addition compounds of quinine salts with phenol, as an example of which that of the hydrochloride with phenol may be mentioned, $2(C_{20}H_{24}N_2O_2HCl) \cdot C_6H_6O \cdot 2\,H_2O$ (18). And Jobst has prepared an addition compound of quinine alkaloid and phenol (17). Mono- and dibenzyl addition products are likewise known (37).

The action of quinine when fused with caustic alkalies affords a further insight into its composition. Betaiutidine, lower aliphatic acids, such as acetic, butyric, and propionic, quinolidine, and paramethoxylepidine are formed (20, 41).

Digitized by Google



Betalutidine Quinolidine Paramethoxylepidine.

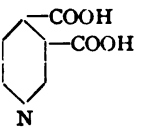
From this it seems evident that the alkaloid contains a methoxy-group (29, 41), and that its position is the same as that in quinolidine and paramethoxylepidine. We can easily further prove the presence of a methoxy group by heating the alkaloid at 140° – 150° C. with concentrated hydrochloric or hydriodic acid (29, 63). Methyl chloride or iodide, as the case may be, will be formed. The reaction with potassium hydroxide also indicates the presence of a pyridine ring and a quinoline formation, the latter doubtless with a methoxy group in the para position; either one or both may be present.

Probably the best proof of the internal structure of the quinine molecule is furnished by the products of its oxidation by various methods. The action of potassium permanganate in alkaline and in acid solution, both hot and cold, of chromic acid, and of nitric acid has been extensively studied, principally by Kerner, Skraup, and Ramsay and Dobbie.

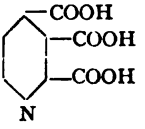
Potassium permanganate gradually added to a solution of quinine in sulphuric acid, keeping the temperature below 10° C., causes the splitting off of a molecule of formic acid, and the production of a new body called quitenine, $C_{19}H_{22}N_2O_4 + 4H_2O$ (15, 24, 26, 57). Since the oxidation occurs with so much ease, it is probable that it occurs at the point of unsaturation. That is, at an ethylene linking, where, as has been found, addition of halogens and other compounds so easily occurs. If the presence of a condition such as this $-CH = CH_2$ is assumed, we may expect it to form addition compounds, and, upon treatment with permanganate, we may expect it to become COOH and HCOOH. The reaction, in fact, occurs in the way indicated, formic acid and a carboxyl being produced. Quitenine is thus an acid (61). We may further assume that the $-CH = CH_2$ is present in the form of a side chain, since it is so readily detached.

If the oxidation is allowed to proceed more vigorously, for example by hot permanganate or by nitric acid, the resulting products are more numerous (10, 12). One of the most important is cinchomeronic acid (21, 25).

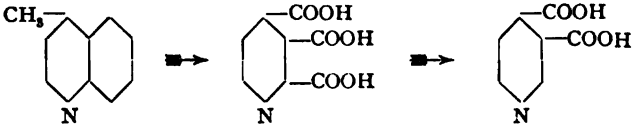
Digitized by Google



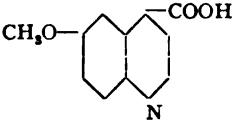
Another is alphacarbocinchomeronic acid (22, 27, 28).



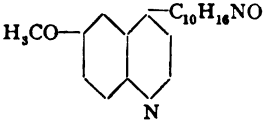
We know that cinchomeronic acid is readily formed by heating alphacarbocinchomeronic acid; in fact the separation of COOH by this means is really a proof of its alpha position. Remembering the probability of the presence of a paralepidine formation in the quinine molecule, as shown by fusion with alkalies, it seems reasonable to find it converted by oxidizers to alphacarbocinchomeronic acid; and then by heat to cinchomeronic,



Under the influence of chromic acid Skraup (23, 24, 32) succeeded in obtaining from quinine an acid $C_{11}H_9NO_3$, which he called quininic acid (33). It is now known to be paramethoxy-gammacarboxyl quinoline



It is, therefore, from all the above reactions, generally concluded that quinine is a quinoline derivative, containing a methoxy group in the para position, and another, second group, in the gamma position. Or it is a derivative of 4-carboxy-6-methoxyquinoline, We may then write it

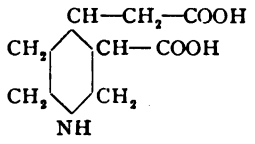


Digitized by Google

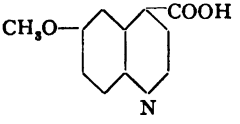
The molecule of the alkaloid thus appears to comprise two rather distinct halves, the carbon, oxygen, and nitrogen being equally divided between them. Hot permanganate or nitric acid splits off the first half and converts it into compounds from which its structure may be inferred with some certainty. The second half molecule requires different treatment.

If we treat quinine with acetylchloride, or similar compounds, it is easy to prepare monoacetylquinine (29). We find also accounts of the preparation of the monopropionyl-(29) and benzyl-(11, 13) quinine. In the preparation of these hydrogen is set free as always in exchanging an acyl for the hydrogen of hydroxyl. The alkaloid then contains an hydroxyl; and it is in the second half of the molecule, for otherwise we should expect to find it in the above quininic acid. That is, we should have by oxidation hydroxyquininic acid instead of quininic acid.

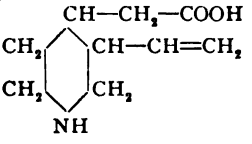
Using chromic acid as the oxidizing agent there is obtained from quinine cincholoiponic acid,



quininic acid,



and also meroquinene,

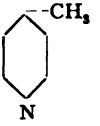


(32, 40, 59, 62).

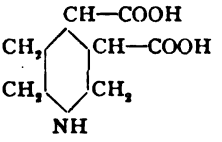
The structural formula of cincholoiponic acid is not firmly established, but the above formula is a possible and a probable one (62). We believe it is a secondary base because it forms nitrosamine, acetyl, and benzoyl derivatives; and the two carboxyls, indicated by its dibasic properties, are in the ortho position, since it yields a fluorescein by treatment with resorcinol and zinc chloride. It is saturated and a very stable acid, but dilute sulphuric acid at

Digitized by Google

about 270° C. breaks it up, one of the resulting products being gammapicoline,

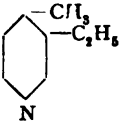


Oxidation converts the acid into loiponic acid,

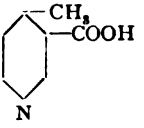


It is to be noticed in both acids that they are pipecoline derivatives, and cincholoiponic acid is gammapipecolinedicarboxylic acid.

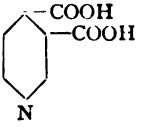
Meroquinene, $C_9H_{16}NO_2$, is alike a pronounced acid and a base. It forms salts with bases, esters with hydrochloric acid and alcohol; and in basic properties it is secondary, yielding nitrosamine and acetyl derivatives. Meroquinene is converted by hydrochloric acid at 240° C. into gammamethylbetaethylpyridine,



Oxidation changes this latter into homonicotinic acid,



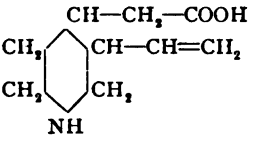
and cinchomeronic acid,



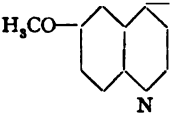
Upon oxidizing meroquinene by permanganate cincholoiponic and formic acids result. From all the above properties it seems probable that meroquinene is a hydrogenated pyridine body (the nitrogen is imide, while in quinine it is not; and its formula is $C_9H_{15}NO_2$); that this pyridine ring has a methyl group attached in

Digitized by Google

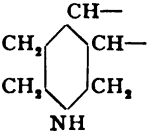
the gamma position, and a side chain of at least two carbon atoms in the beta. This side chain is evidently the same one that furnishes formic acid in the preparation of quitenine. And since it readily oxidizes by permanganate it seems to be $-CH=CH_2$. If it is attempted to express these ideas in graphic form this might be used,



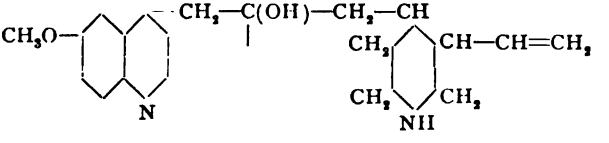
Quinine, therefore, appears from its various reactions and decomposition products to contain in the first half of the molecule the quinoline grouping with an attachment in the gamma position already described,



And in the second half a piperidine ring,



containing also an attachment in the gamma position; and in addition one in the beta position. The two nuclei must be joined by the chain of three carbon atoms, one of which becomes carboxyl in the formation of quininic acid, and another of which becomes carboxyl in cincholoiponic acid, or better in meroquinene where there is only one carboxyl. Constructing then a graphic formula as far as the composition has been developed we have



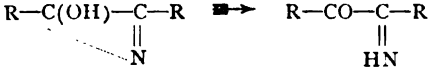
And the three-carbon chain must contain the hydroxyl of the molecule, since it appears neither in the quinoline nucleus, nor in the piperidine nucleus, nor in any of the oxidation products.

It was mentioned above that quinine forms addition compounds

Digitized by Google

among them being quinine mono- and dialkyl iodide. It is not difficult to prepare the mono- or the dialkyl derivative at will, by modifying the conditions of the reaction. Moreover, two isomeric monoethyl iodides, with very different melting points, have been prepared. Strecker (8), in 1854, found that quinine monoethyliodide melting at 211° C. results from the action of ethyl iodide on quinine, while Skraup and von Norwall (60), in 1894, prepared an isomer of Strecker's preparation melting at 93° C. Quinine hydriodide when heated with ethyl iodide forms quinine hydriodideethyliodide, and this with ammonia splits off hydriodic acid, leaving a monoethyl iodide (58). The fact that the two isomers require different processes of preparation indicates a difference in basicity of the nitrogen atoms to which the alkyl iodides are attached; the high melting one being easily prepared shows that in this case the more basic nitrogen is engaged. And, further, when the high melting isomer is treated with cold potassium hydroxide no reaction occurs; but if potassium hydroxide is used upon the diethyliodide derivative the reaction is like that of a methoxyquinolinealkyliodide. This seems to show that the first alkyl iodide is not in the quinoline group of the quinine molecule, and hence the nitrogen of the second half of the molecule is the more basic. It is to this nitrogen that acids and alkylhalides most readily attach themselves (49).

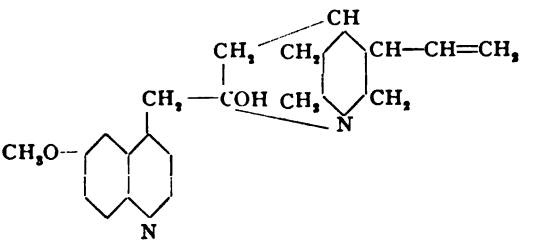
Quinicine (7), occurring naturally in cinchona bark (16), already mentioned as an isomer of quinine produced by various methods, and considered as identical with quinotoxine (67), is of interest at this point. It is an oil, gradually hardening, non-fluorescent, dextrorotary, and forming salts. Its oxidation products are the same as those of quinine. In the formation of an hydrazone (67), quinotoxine phenylhydrazone, $C_{20}H_{24}N_2O(N_2H \cdot C_6H_5)$, we recognize the presence of a ketonic oxygen in quinotoxine, converted from an hydroxylic oxygen in quinine. The change is theoretically represented thus:



It is helpful in locating the hydroxyl as attached to a carbon-atom, itself attached to a nitrogen atom.

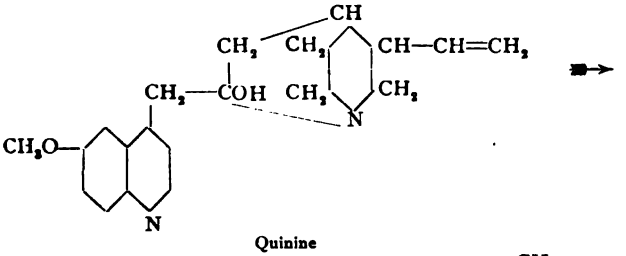
We may therefore, construct the quinine molecule somewhat as follows:

Digitized by Google

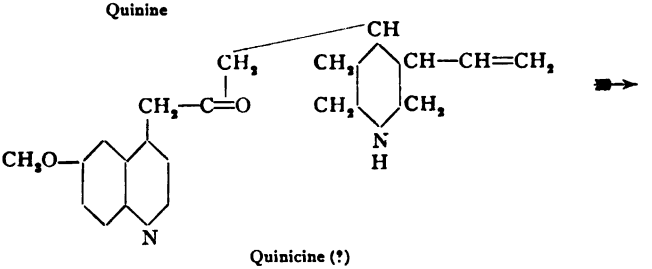


Quinine

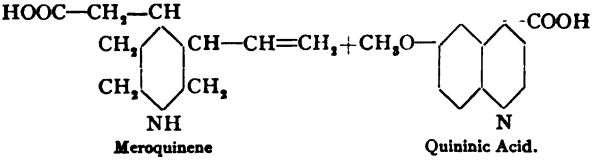
We know the molecule contains a quinoline group, a piperidine ring and saturated side chain, connected together at the two gamma positions by a chain of three carbon atoms bearing one hydroxyl, We further know that the nitrogen of the piperidine ring is more basic than that of the quinoline, and this lends probability to the linking of the hydroxylic carbon to the nitrogen of the piperidine. This arrangement also explains the production of secondary bases, meroquinene and cincholoiponic acid, from tertiary quinine, if we assume that the first step in the oxidation is a change to the ketonic form.



Quinine



Quinicine (?)

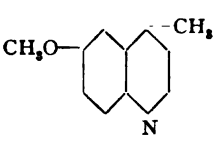


Meroquinene Quininic Acid.

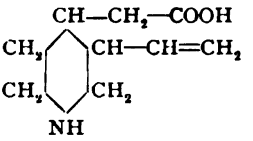
The two bodies quinene and apoquinene lend still further proof of the structure of quinine, especially of the second half of the molecule.

Digitized by Google

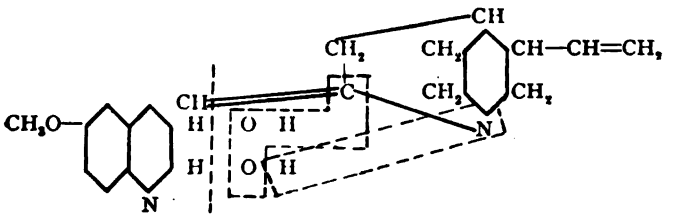
Phosphorus pentachloride acting upon quinine hydrochloride in chloroformic solution replaces the quinine hydroxyl by chlorine, the resulting non-fluorescing compound being quinine chloride, $CH_3O.C_9H_5N.C_{10}H_{15}Cl.N$. On boiling this with alcoholic potash a molecule of hydrochloric acid is split off, leaving quinene, $CH_3O.C_9H_5N.C_{10}H_{14}N$ (38, 41). Quinene is thus seen to be quinine less (OH + H), or less H_2O. Its properties are interesting. It is a bitertiary base (65), giving the thalleioquin reaction and fluorescing stronger than quinine. It is unsaturated, readily adding two but only two atoms of bromine (quinene dibromide, $C_{20}H_{22}Br_2N_2O$), which latter are removable as two molecules of hydrobromic acid leaving dehydroquinene, $CH_3O.C_9H_5N.C_{10}H_{12}N$ (41). Heated with acetic or phosphoric acid, quinene is converted into paramethoxylepidin and meroquinene (41, 62).



and



Assuming the following formula for quinene, which seems a probable one after removing hydroxyl and a neighboring hydrogen from quinine, the reaction may be represented as follows:



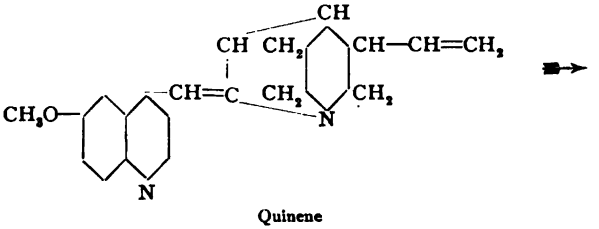
The reaction and the probability that it occurs in the above manner is confirmative of the previously assumed linking of the hydroxylic carbon with the nitrogen; as well as of the composition of the entire second half of the molecule.

When quinene is heated to 190° C. with hydrobromic acid there are formed ammonia, methylbromide, and a new compound apoquinene, $(HO)C_9H_5N.C_{10}H_{12}(OH)$ (41, 59). The ammonia comes from the second half of the molecule. This we know because, when oxidized, apoquinene yields parahydroxycinchoninic acid, showing that the nitrogen of the quinoline group is still undisturbed (59). The methyl bromide is from the methoxy group in the first

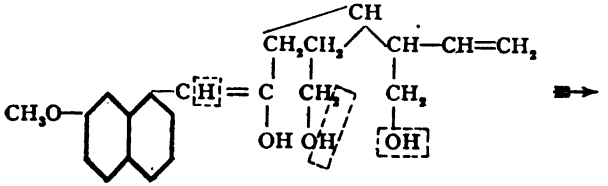
Digitized by Google

half, the CH_3O being changed to OH; and the apoquinene, as will be shown, is from the remaining portions of the two halves of the molecule.

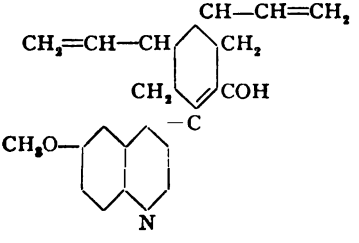
Apoquinene, in addition to the hydroxyl on the quinoline half of the molecule, contains another hydroxyl. Its character is phenolic, since it shows the customary reaction with alkalies followed by carbonic acid. Bromine does not add itself to apoquinene, an indication of the absence of aliphatic unsaturation (41, 59). Evidently then apoquinene is composed of a parahydroxyquinoline group linked in the gamma position to a benzene ring bearing one hydroxyl. We may, perhaps, account for this condition by considering the nitrogen of quinene as replaced by three hydroxyls, this producing an unstable body which loses water and then rearranges from a cycloxene with two unsaturated side chains to a benzene compound with saturated side chains.



Quinene

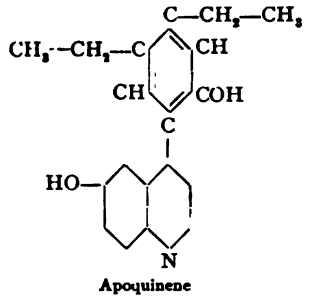


Incomplete Unstable



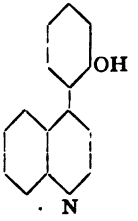
Rearranges

Digitized by Google



Apoquinene

The positions of the hydroxyl and of the ethyl groups have been worked out by an elaborate and ingenious method of Königs. By successively converting the ethyl groups of the above formula into carboxyls, he has succeeded in establishing their positions to each other as ortho; and, after removal of both, the resulting quinoline-phenol is identical with a synthetic body known to be a gamma-phenolquinoline of this formula, 59,

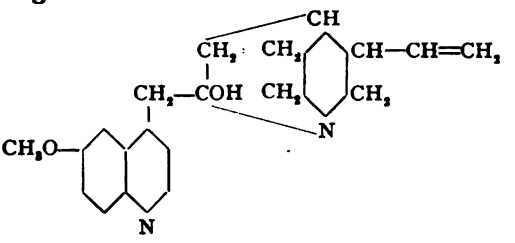


Thus we seem to find in quinene and apoquinene reactions that are fairly accounted for by theory as expressed in the formula of Miller and Rohde, which has been used above for quinine. Many other formulas have been suggested.

Résumé. — Quinine is the principal alkaloid in cinchona bark. It is associated with other alkaloids and closely resembles, chemically, another of the important ones, cinchonine. It is readily converted into its isomers, some of which are isoquinine, pseudoquinine, niquine, and quinicine. It is unsaturated, easily adding two halogens, less easily two more. It contains a methoxy and an hydroxyl group; also an unsaturated side chain. It is in one half of its molecule a quinoline derivative, containing methoxy in para position and another group in gamma position. The second half is a piperidine ring with a side chain of two carbon atoms at beta, and one of three carbons at gamma. The three carbon chain contains the hydroxyl group and connects the two half molecules;

Digitized by Google

and is thought also to be further linked to the piperidine nitrogen at its hydroxylic carbon. Its probable graphic formula, as constructed by Miller and Rohde and others after consideration of the above facts, is given as follows:



Experimental Part.

In the laboratory an attempt has been made to prepare quitenine and quitenol, and also to verify some of the statements of writers regarding them.

The customary method of preparing quitenine, as given by Kerner and others (15, 32, 40, 57, 61), is by the gentle oxidizing action of potassium permanganate in the cold. Quinine sulphate in definite amount is dissolved in water and just enough sulphuric acid is added to make sure that all the potassium of the permanganate, subsequently introduced, becomes potassium sulphate. The quitenine is precipitated with the manganese dioxide, and, after filtering, it is extracted from the dioxide by repeated washing with hot alcohol.

In the experiments under discussion the amounts of quinine and permanganate used were kept within the proportions advocated by Skraup (26), 5 alkaloid to 5.5 permanganate. This was because Skraup records a yield of seventy-five per cent. of theory; but the reaction would seem to take place 5 alkaloid to 6.5 permanganate. The equation is probably as follows:

$$3(C_{20}H_{24}N_2O_2)_2H_2SO_4.8H_2O + 16KMnO_4 + 5H_2SO_4$$
$$= 6C_{19}H_{22}N_2O_4 + 6HCOOH + 16MnO_2 + 8K_2SO_4 + 32H_2O.$$

Adhering, however, to the proportions stated, the quantities employed were:

Quinine sulphate $(C_{20}H_{24}N_2O_2)_2H_2SO_4.8H_2O$ . .	100 gm.
Potassium permanganate.	80 "
Acid sulphuric absolute (2 N acid used) . . .	13.8 "

Digitized by Google

The quinine sulphate was dissolved in about two liters of water containing the acid and the permanganate added by drops in the form of a solution about 4 per cent. in strength. The reaction was conducted below 10° C., the solution being stirred during the entire time of adding the oxidizer.

In extracting the quitenine from the manganese dioxide by means of dilute alcohol (alcohol 1, water 1) repeated extraction at as high a temperature as possible was found necessary. This step in the process was found quite unsatisfactory as much time and alcohol are consumed, and, moreover, some quitenine is lost. After purifying by one recrystallization from hot dilute alcohol twenty-seven grams of quitenine were found. This is 41.5 per cent. of theory. In subsequent experiments good results were obtained by dissolving the quitenine and manganese dioxide together in aqueous sulphurous acid, adding ammonium chloride and then neutralizing with ammonia. The quitenine separates out. But even more desirable is the method of extracting the mixed precipitates with boiling 5 per cent. sodium hydroxide solution. Three extractions will remove practically all of the quitenine and occupy only a few minutes time. The sodium hydroxide solution containing the sodium salt of quitenine is then exactly neutralized by sulphuric acid using litmus. Almost a quantitative separation of quitenine occurs. Or, an excess of boric acid can be used in place of exact neutralization with sulphuric acid. Using the same quantities of starting materials and extracting with alkali followed by sulphuric acid a yield of 43.3 per cent. of theory was obtained.

Quitenine was purified by repeated recrystallizations from boiling dilute alcohol. At first it is colorless, but in the light it soon turns slightly brown. It was also purified by dissolving in ammonia water and reprecipitated by passing a stream of CO_2 through this. This process repeated two or three times, followed by crystallization from hot dilute alcohol yields a very pure product.

Quitenine was found to be insoluble in most ordinary solvents. It is practically insoluble in the following solvents cold: Carbon tetrachloride, chloroform, water, absolute alcohol, methyl alcohol, amyl alcohol, acetone, aniline, ethyl acetate, benzene, nitrobenzene, glycerine, ether anhydrous, benzin, carbon disulphide, xylene, amyl acetate, kerosene, aqueous solution boric acid, alcohol 95 per cent., ether, and mixtures of carbon tetrachloride, with chloroform and alcohol. It is almost wholly insoluble in the above at boiling tem-

Digitized by Google

perature except in the case of water, absolute and 95 per cent. alcohol, methyl, and amyl alcohols. It is quite soluble in cold pyridine and readily in sulphuric, sulphurous, nitric, hydrochloric, and acetic acids; and in ammonia, sodium or potassium hydroxide solutions, less easily in sodium carbonate or ammonium carbonate solutions cold, but readily hot. When a strong solution of sodium hydroxide (40 per cent.) is added in excess to the dry quitenine a solution is at first formed, then gelatinization occurs. Addition of water produces again a clear solution. No ammonia is liberated during the operation, nor does sodium carbonate set free any ammonia, even at boiling temperature.

Quitenine is soluble in phenol. If the crystals of phenol are warmed just sufficiently to melt them, quitenine will readily dissolve in the resulting fluid. Water added to the phenol reduces its power as a solvent, the more water present the less it will dissolve. But when the phenol is mixed with 95 to 98 parts of water it will still dissolve much more quitenine than pure water. Experiment has shown that beautiful needle crystals may be obtained by dissolving quitenine in melted phenol, adding 95–98 parts of hot water and allowing the whole to cool very slowly.

Crystals prepared as described were washed with cold water until free from the odor of phenol and dried. Upon washing them with ether they do not give up to the ether any phenol detectable by bromine water. They are slightly soluble in cold water, readily so in hot water and in cold alcohol. Solutions in water give a strong reaction in the form of a white precipitate with bromine water. The alcoholic solutions upon being freed from alcohol, or even highly diluted, give the same white precipitate. Quitenine itself is not sufficiently soluble in water or alcohol to affect bromine water. Phenol is evidently present in a combined state in the crystals. This is further indicated by heating the dry crystals to incipient browning. The odor of phenol is plainly noticeable; and the water of crystallization, which is first expelled, if condensed and mixed with bromine water gives the usual white precipitate. Quitenine itself, when heated as above, gives nothing resembling these results. The melting point, too, is lowered in these crystals. Quitenine has a melting point variously stated at 265° to 286° C., depending upon the time of heating and some other factors. The crystals in question melted with decomposition in various trials between 238° C. and 245° C. Quickly heated these crystals melted

Digitized by Google

at 243° C., while the quitenine from which they were prepared, when heated the same length of time, melted at 274° C., decomposing as it always does.

Quitenine is found to dissolve in melted orthocresol nearly as readily as in phenol. Crystals are deposited from the solution upon dilution and cooling, all the tests with bromine water, the odor on heating, and the cresol in the water expelled upon heating are the same. The tests may be carried out with only a modification to provide for the smaller solubility in water of the cresol over phenol.

Quitenine upon heating with hydriodic acid forms quitenol. The equation is

$$C_{19}H_{22}N_2O_4.4H_2O + HI = C_{18}H_{20}N_2O_4 + CH_3I + 4H_2O.$$

The methoxy group of the original quinine molecule is changed to hydroxyl and a molecule of methyl iodide formed. A quantity of quitenol has been prepared in the laboratory in contemplation of further experimental work on the constitution of quinine.

In preparing quitenol the method as given by v. Bucher (57) was used, the proportions being

Quitenine	5 gms.
Acid Hydriodic, sp. gr., 1.70	50 "

The solution was boiled under a reflux condenser for three hours, while a stream of CO_2 was constantly passing. v. Bucher states that after about three hours boiling a portion removed will no longer give a reaction with silver nitrate. But this did not prove to be so; and in one trial the boiling was continued six hours, frequent tests being made during the operation. Even at the close there was present an abundance of uncombined acid. Indeed 50 gm. of hydriodic acid, of the strength designated, to be wholly converted to methyl iodide would consume about 80 gm. of quitenine.

To separate the quitenine at the close of the reaction hot water may be added, then sodium bisulphite to decolorization and finally sodium hydroxide to neutrality. The quitenol separates from the neutral solution in small needle-shaped crystals resembling quitenine. They are soluble in acids, alkalies, and hot alcohol, from which latter it was recrystallized for purification. In water, cold alcohol, and ether it is practically insoluble. The largest yield obtained was 65.6 per cent. of theory.

This work was undertaken at the suggestion of Professor Mars-

Digitized by Google

ton Taylor Bogert, of the Organic Laboratory of Columbia University, and will be continued under his supervision and direction.

CHRONOLOGICAL BIBLIOGRAPHY.

1. 1820. **Pelletier and Caventou.** "Recherches chimiques sur les Quinquinas." Ann. Chim. Phys. (2), 15, 289–318.
2. 1820. **Pelletier and Caventou.** "Des Recherches chimiques sur les Quinquinas." Ann. Chim. Phys. (2), 15, 337–365.
3. 1823. **Dumas and Pelletier.** "Recherches sur la Composition eléméntaire et sur quelques propriétés characteristique des bases salifiable organiques." Ann. Chim. Phys. (2), 24, 163–191.
4. 1831. **Liebig, J.** "Ueber einen neuen Apparat zur Analyse organischer Körper, und über die Zusammensetzung einiger organischen Substanzen." Ann. Pogg., 21, 1–43.
5. 1838. **Regnault, V.** "Neue Untersuchungen über die Zusammensetzung der organischen Basen." Ann. Chem. Pharm., 26, 10–41.
6. 1838. **Liebig, J.** "Bemerkungen zu vorstehender Abhandlung." Ann. Chem. Pharm., 26, 41–60.
7. 1853. **Pasteur, L.** "Recherches sur les alcaloïds des quinquinas." Compt. rend., 37, 110–114.
8. 1854. **Strecker, A.** "Recherches sur diverses questiones." Compt. rend., 39, 49–63.
9. 1854. **Strecker, A.** "Untersuchungen über die Constitution des Chinins." Ann. Chem. Pharm., 91, 155–170.
10. 1858. **Schutzenberger, P.** "Recherches sur la quinine." Compt. rend., 47, 81–82.
11. 1858. **Schutzenberger, P.** "Note sur les dérivés benzoïques de la quinine, de la cinchonine, et de la strychnine." Compt. rend., 47, 233–235.
12. 1858. **Cloez, S., and Guignet, E.** "Transformation de l'azote des matières en nitrate de potasse." Compt. rend., 47, 710–712.
13. 1858. **Schutzenberger, P.** "Untersuchungen über Pflanzenbasen." Ann. Chem. Pharm., 108, 346–354.
14. 1865. **Hesse, O.** "Ueber Chinin und Chinidin." Ann. Chem. Pharm., 135, 325–344.
15. 1869. **Kerner, G.** "Ueber die Einwirkung von übermangansauren Kali auf Chinin." Zeitsch. f. Chemie, N. S., 5, 593–596. Frankfurt a. M.

Digitized by Google

16. 1871. **Howard, D.** "On an Alkaloid from Cinchona Bark hitherto Undescribed." Jour. Chem. Soc., 24, 61–64.

17. 1875. **Jobst, J.** "The Salicylate and Carbolate of Quinine." Phar. Jour. Trans. (3), 5, 986.

18. 1876. **Jobst, J., and Hesse, O.** "Ueber Verbindungen von Phenol mit neutralen Chininsalzen." Ann. Chem. Pharm., 180, 248–252.

19. 1877. **Hesse, O.** "Ueber die Alkaloide der Chinarinden." Ber., 10, 2152–2163.

20 1878. **Wischnegradsky and Butlerow, A.** "Communication." Bul. Soc. Chim. (2), 30, 27–28.

21. 1878. **Ramsay, W., and Dobbie, J. J.** "Zur Kenntniss des Chinins und der verwandten Alkaloide." Ber., 11, 324–327.

22. 1879. **Hoogewerff, S., and van Dorp, W. A.** "Ueber die Oxidation von Chinin vermittelst Kalium permanganat." Ber., 12, 158–161.

23. 1879. **Skraup, Z. H.** "Oxidationsprodukte des Chinabasen." Ber., 12, 230–234.

24. 1879. **Skraup, Z. H.** "Ueber Oxydationsprodukte des Chinins." Ber., 12, 1104–1107. Wien.

25. 1879. **Weidel, H., and v. Schmidt, M.** "Ueber die Bildung der Cinchomeronsäure, aus Chinin und deren Identität mit Pyridindicarbonsäure." Ber., 12, 1146–1153. Wien.

26. 1879. **Skraup, Z. H.** "Ueber das Chinin." Ann. Chem. Pharm., 199, 344–359. Wien.

27. 1879. **Ramsay, W., and Dobbie, J. J.** "On the Decomposition Products of Quinine and Allied Alkaloids." Jour. Chem. Soc., 35, 189–196. Glascow.

28. 1880. **Hoogewerff, S., and van Dorp, W. A.** "Ueber das Verhalten der Chinaalkaloide gegen übermangansaures Kalium." Ann. Chem. Pharm., 204, 84–118.

29. 1880. **Hesse, O.** "Untersuchungen über die Constitution einiger Alkaloide der Chinarinden." Ann. Chem. Pharm., 205, 314–357.

30. 1881. **Rennie, E. H.** "On a New Derivative of Quinine." Jour. Chem. Soc., 39, 469–471.

31. 1881. **Claus, A., and Mallmann, F.** "Methyl und Aethylderivative des Chinins." Ber., 14, 76–80.

32. 1881. **Skraup, Z. H.** "Ueber Chinin und Chinidin." Monatsch., 2, 587-609. At Professor Lieben's University Laboratory.

Digitized by Google

33. 1882. **Skraup, Z. H.** "Zur Constitution des Chinins und Chinidins." Monatsch., 4, 695–699. Wien.

34. 1883. **Mazzara, G.** "Sopra un nova composto della chinina col cloralio." Gazz. Chim., 13, 269–272. Torino.

35. 1883. **Mazzara, G.** "Sopra l'azione di alcune aldeidi aromatiche sulla chinina." Gazz. Chim., 13, 367–369.

36. 1883. **Mazzara, G.** "Monocloro e dicloroaceto di chinina." Gazz. Chim., 13, 525–527.

37. 1883. **Mazzara, G., and Posetto, G.** "Sull'azione del cloruro di benzile sulla chinina." Gazz. Chim., 13, 529–532.

38. 1884. **Comstock, W. J., and Königs, W.** "Zur Kenntniss der Chinaalkaloide." Ber., 17, 1984–1996. Munich.

39. 1887. **Comstock, W. J., and Königs, W.** "Additionsprodukte von Chinaalkaloide." Ber., 20, 2510–2527. Munich.

40. 1889. **Skraup, Z. H.** "Zur Constitution der Chinaalkaloide." Monatsch , 10, 39–50. Graz.

41. 1890. **Königs, W.** "Ueber die Bildung von Lepidinderivaten aus Chinen und Cinchen." Ber., 23, 2669–2679. Munich.

42. 1891. **Grimaux, E., and Arnaud, A.** "Transformation de la cupréine en quinine." Compt. rend., 112, 774–775.

43. 1891. **Grimaux, E., and Arnaud, A.** "Sur la quinéthylene, base homologue de la quinine." Compt. rend., 112, 1364–1367.

44. 1891. **Lippmann, E., and Fleissner, F.** "Ueber Einwirkung von Jodwasserstoff auf Chinin und das Isochinin." Monatsch., 12, 327–337. Wien.

45. 1891. **Skraup, Z. H.** "Ueber die Einwirkung von Jodwasserstoffsäure auf Chinaalkaloide." Monatsch., 12, 431–434. Univ. Graz.

46. 1891. **Lippmann, E., and Fleissner, F.** "Ueber die Einwirkung von Jodwasserstoff auf Chinin und Cinchonin." Ber., 24, 2827–2829. Wien.

47. 1891. **Hesse, O.** "Ueber das Verhalten des Cupreïns und Chinins zu Jodmethyl." Ann. Chem. Pharm., 266, 240–245.

48. 1892. **Grimaux, E., and Arnaud, A.** "Transformation de la cupréine en quinine et en bases homologues." Bul. Soc. Chim. (3), 7, 304–312.

49. 1892. **Grimaux, E.** "Sur les iodométhylates de quinine." Compt. rend., 115, 117–120.

50. 1892. **Grimaux, E.** "Sur quelques sels doubles de quinine." Compt. rend., 115, 608–610.

Digitized by Google

51. 1892. **Comstock, W. J., and Königs, W.** "Ueber Halogenderivative der Chinaalkaloide." Ber., 25, 1539–1551. Munich.

52. 1892. **Skraup, Z. H.** "Umwandlung des Chinaalkaloide in Isomere." Ber., 25, 2909–2912. Graz.

53. 1892. **Grimaux, E., and Arnaud, A.** "Ueber die Umwandlung des Cupreïns in Chinin." Ann. Chem. Pharm., 267, 379–380.

54. 1892. **Lippmann, E., and Fleissner, F.** "Ueber Hydrojodverbindungen einiger Chinaalkaloide." Monatsch., 13, 429–439. Wien.

55. 1893. **Skraup, Z. H.** "Umwandlung des Chinins." Monatsch., 14, 428–454. Graz.

56. 1893. **Lippmann, E, and Fleissner, F.** "Ueber Isochinin und Nichin." Monatsch., 14, 553–558. Wien.

57. 1893. **v. Bucher, R.** "Ueber das Quitenine." Monatsch., 14, 598–611. Graz.

58. 1893. **Skraup, Z. H., and Konek von Norwall, F.** "Ueber neue Isomere der Jodäthylverbindungen von Chinaalkaloiden." Ber., 26, 1968–1970. Graz.

59. 1894. **Königs, W.** "Ueber hydrolytische Spaltungen des Chinens und Cinchens." Ber., 27, 900–907. Munich.

60. 1894. **Skraup, Z. H., and Konek von Norwall, F.** "Ueber neue Verbindungen der Chinaalkaloiden mit Aethyljodid." Monatsch., 15, 37–52. Graz.

61. 1895. **Skraup, Z. H.** "Ueber das Cinchotenine." Ber., 28, 12–16. Graz.

62. 1895. **Königs, W.** "Weitere Beiträge zur Kenntniss des Merochinens." Ber., 28, 1986–1991. Munich.

63. 1895. **Lippmann, E., and Fleissner, F.** "Ueber Apochinin und seine Aether." Monatsch., 16, 34–44. Wien.

64. 1895. **Lippmann, E., and Fleissner, F.** "Ueber Hydrirung des Chinins." Monatsch., 16, 630–637. Wien.

65. 1896. **Königs, W.** "Ersetzung von Hydroxyl in Chinaalkaloiden durch Wasserstoff." Ber., 29, 372–374. Munich.

66. 1896. **Konek von Norwall, F.** "Ueber Hydroderivate von Chinaalkaloiden." Ber., 29, 801–805. Budapest.

67. 1900. **Miller, W., Rohde, G., Brunner, J., and Fussenegger, E.** "Beiträge zur Kenntniss der Chinaalkaloïde." Ber., 33, 3214–3237.

68. 1902. **Tafel, J., and Naumann, K.** "Die elektrolytische Reduction des Strychnins und Brucins." Ber., 39, 3291–3299.

ORGANIC LABORATORY, COLUMBIA UNIVERSITY,
May 15, 1905.

Digitized by Google

ADVANTAGES AND APPLICATIONS OF THE ELECTRIC DRIVE.*

By F. B. CROCKER and M. ARENDT.

The great economies effected in many manufacturing establishments by the substitution of electric drive for the older methods of counter-shafting and belting have resulted in the rapid extension of this branch of electrical engineering. Many factory managers anxious to decrease running expenses, or increase the plant output, are led, by a general knowledge of what has been accomplished, to believe that this substitution would produce both results. In many instances the desired results may be obtained, and in others, affairs would not be improved; either owing to the fact that the conditions of operation are not suited to the electric drive or because the wrong types of motors or motor control were employed.

It is impossible to give any exact rule which would determine when to adopt the electric drive, or when not to. Each case should be considered according to its own particular features, and the reasons for and against the change must be carefully studied, in order to be able to decide correctly which system or modification would produce the best results in all respects. It is necessary not only to consider the increased output or reduced power bills, but also to take into consideration the items of first cost, interest, depreciation, maintenance and other facts discussed in detail later.

Electric drive may be divided into three general classes, as follows: *One motor* for the entire plant; *group drive*, when the machines in each section or bay are driven from one motor common to that section only; *individual drive*, when each individual tool is equipped with its own motor.

The Common Motor Drive is equivalent to the ordinary engine or other prime mover drive, and employs like them a system of counter-shafts and belts, its advantage being the convenience of electric transmission of power, in comparison with a steam engine

* Portion of Lecture Notes on Electric Power, Electrical Engineering Department Columbia University.

Digitized by Google

plant and its attendants, as well as reduced first cost of the equipment. It is also employed when the plant is too small to be economically divided into groups or operated by individual motors. The running efficiency under variable loads thus secured is higher than that of the steam or gas-engine, and while this is an advantage, the saving made is too small to consider by itself.

The Group Drive is a compromise between one common motor and individual machine drive, and its employment is frequently advisable. For example, consider a factory having no rush season, but a steady demand for its finished product, so that the work can be turned out according to a certain definite schedule, with the labor so divided that every two or more men operate a certain group of tools, which are used therefore in rotation, and not at the same instant. In a case like this, only one motor is necessary for each group, but it must be large enough to drive the heaviest machine connected to it. The connections are made by counter-shafts, friction-clutches and belts, so arranged that only the particular machine in use is being driven.

It is advisable in such an equipment, to have tools requiring approximately the same power in the same groups, because by so doing, the average size of the motors will be kept down and the first cost reduced.

Group drive is to be recommended, when several similar machines are to be run, each machine requiring only a small amount of power, as for instance in the case of a collection of sewing machines, small saws, grinders, polishers, buffers, etc.

Individual Drive. — When the establishment is large and wide ranges of speed are desired, with machines differing greatly in capacity and performing totally different functions, individual drive is to be recommended, on account of the independence of the various machines, reduction in shafting and belting losses, etc. The motor may be connected to the driven apparatus by one of three general means, *i. e.*, direct-connecting, gearing or belting. The first method is employed when the normal speed of the machine is high and corresponds to that of the motor. Very low speed apparatus should not be driven directly, because the cost of the motor would be excessive; low speed motors being larger than high speed ones of the same capacity. When the required reduction of motor speed is small, and does not exceed 3 to 1, belting answers well if the distance between driving and driven shafts can

Digitized by Google

be made considerable and the power to be transmitted is not great. If the distance between shaft centers is necessarily small (less than four times the diameter of the driving pulley) and the power to be transmitted is considerable, say over 10 h.p., a modified form of belting, *i. e.*, noiseless chain drive is to be recommended. When reduction of driving speed is large and the motor can be placed close to the tool, gearing is to be recommended as the means for transmitting the power. The flexibility of the belt drive is sometimes an advantage since it does not produce the shock upon the motor due to sudden load variations; as for example, those occuring in punching and shearing.

The conditions under which machinery operates in regard to varying speed and power required of the driving motor may be divided into four classes, and a special type of motor is usually best suited to each of these divisions.

(*a*) Work which requires the motor to operate automatically at a constant speed, regardless of load changes or other conditions.

(*b*) Work requiring frequent starting and stopping of the machine, and wide variations in speed, including sometimes rapid acceleration.

(*c*) An approximately steady load, or where the work varies as some function of the speed, should it change.

(*d*) Work in which the power varies regardless of the speed, or where speed variations with constant torque may be desired.

The first case (*A*), applies to line shaft equipments, with many machines operated by the same motor; and where *slight* speed variations may be allowed, the alternating current induction motor, the direct current shunt or slightly compounded motor would answer, depending naturally upon the character of electric current available. A *special refinement* of this problem is encountered in the driving of *textile machines* where a slight speed variation might influence the appearance of the finished product, *in such instances the alternating current motors, polyphase induction or polyphase synchronous are necessary*, because the speed of the direct current motors will vary considerably with voltage changes and variation in temperature which occurs after several hours of operation. Whereas the speed of the alternating current motors, unless the voltage varies greatly, is primarily dependent upon the frequency of the supplied current.

The second class (*B*) is divided into two parts, the first being ap-

Digitized by Google

plicable to electric traction and crane service, for which the motor is frequently started and stopped, *and rapidly accelerated at starting;* or where the speed is to be adjusted automatically to the load, slowing down when heavily loaded or climbing a steep grade. These conditions are well satisfied by the series motor, of either

FIG. 1. Direct-connected blower.

the direct or alternating current types, depending upon the current supplied. Elevator service is of this class, as regards frequent starting and stopping, but after being rapidly accelerated it calls for a speed independent of the load; therefore, to obtain both requirements, elevator motors when of the direct current type are heavily over-compounded, to give the series characteristic at starting; then, when the motor is up to speed, the series field winding

Digitized by Google

is short-circuited and it operates as a shunt machine. If only alternating current is available the polyphase induction motor should be employed, but for powerful starting torque either slip-ring or compensator control would be necessary. In the second subdivision of this class the motor must be started and stopped frequently, *and not rapidly accelerated*, but on the contrary simply "inched" forward at start, as met with in the operation of printing presses and similar equipments. These conditions of service are satisfied by a direct-current compound motor, provided with double armature and series-parallel control of the machine as manufactured by the

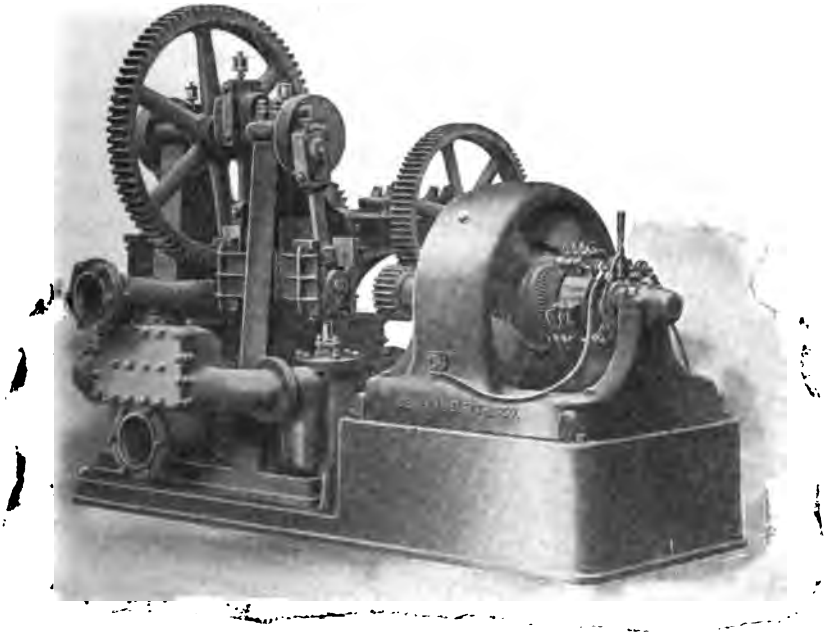


FIG. 2. Vertical triplex double acting pump connected to motor by gearing.

C. & C. Electric Company. They are also well satisfied by the scheme of having a double or variable potential source of current supply for the working motor, low voltage at starting and "inching" positions and higher values at running points. These features are supplied by the Bullock-Teazer system, or by the Ward-Leonard motor-dynamo equipment, the latter, however, being so expensive that its use is almost entirely restricted to the operation of gun turrets, etc.

Digitized by Google

The third class (*C*) applies to the operation of pumps, simple fans or blower equipments and its requirements are best satisfied by the series motor, since the maximum torque is required at starting. *It must be, however, either geared or direct-connected* to the apparatus, because the breaking of the belt or the sudden removal of the load would cause the motor to race and become injured. Fig. 1 is an illustration of a direct-connected blower, and Fig. 2 shows a geared pump. The operation of pumps by electric motors is usually accomplished by gearing, since ordinary plunger pumps do not operate efficiently if driven in excess of fifty strokes per minute, and to accomplish this by direct connection would demand a very low speed and costly motor. Centrifugal pumps operating at higher speeds may be direct connected.

The fourth class (*C*) is found in ordinary machine shop practice. where operation at maximum cutting or turning speed allowable requires the number of revolutions of the work or tool to vary inversely as the diameter of the piece of material being worked upon; this condition is satisfied best by the direct-current shunt

FIG. 3. 24-inch screw-cutting lathe driven by a shunt motor.

or slightly compounded motors, as they are readily controlled in speed by variation of applied voltage, shunt field weakening, etc. Fig. 3 is an illustration of a 24-inch lathe; the driving element is a shunt-wound motor, supplied with current from a multiple voltage system and equipped with a 21-point controller; it drives through a silent chain to a sprocket which may be connected directly to the spindle or through either of two back gear combinations. The first combination gives a variation in speed

Digitized by Google

of 1 : 2.68 and through the second a further change of 1 : 2.63 is obtainable. The highest speed of the motor is 1,270 revolutions per minute and the corresponding speeds of the spindle 285, 108 and 40.4 revolutions per minute. The upper twelve speeds of the motor when driving the spindle directly, the same on the first gear combination, and the upper eighteen on the second, constitute the tool's working speeds, 42 in all. The motor will give an output of 3 h.p. at any speed within this range. Obviously the motor may be run on slower speeds at reduced power, and with the slowest gear combination, as low as four revolutions per minute of the spindle is possible. These extremely low speeds are convenient when setting up work, or when a very low cutting speed is desirable. The controller is manipulated from a hand wheel supported on the carriage, the connection being through gears and a spindle shaft, so that the motor is under instant control of the operator at whatever position along the bed the carriage may happen to stand. The same conditions of service, as above outlined, are met in the case of drilling, milling, surfacing and turning machinery.

FIG. 4. Contained motor drive on a 30-inch drill press.

In the general operation of variable-speed tools, direct-current motors are used, as alternating current induction motors are not adapted to efficient or convenient methods of speed variation, usually depending in such cases upon variable gearing or cone pullies.

When the electric drive has been properly applied the advantages derived may be listed as follows:

1. *Saving in Power.* — This is generally the first point to be considered, but it is by no means the most important, as the cost of power in most factories is only one to three per cent. of the cost of the finished product, the cost of labor being usually many times greater. It is a fact, however, that due to the absence of belting

Digitized by Google

and shafting losses, and the cutting off of electric current whenever an individually operated machine is stopped, the saving of power is a much larger quantity than might be expected. In a paper before the American Institute of Electrical Engineers by R. T. E. Lozier, the following data was given :

" From the data that has been collected on power transmission in industrial shops, much of which is to be found in the transactions of the various engineering societies and in the magazines, it appears that if a certain maximum horse-power is required by all the tools of a shop, say 100 h.p., it will require at least 100 h.p. additional to transmit this effective power by belts and shafting. This loss of 100 h.p. remains constant whether the effective horse-

FIG. 5. Heavy milling machine with motor drive.

power is reduced or not. This means that 200 h.p. must be generated. Should these same tools be driven by individual motors, instead of 100 h.p. being required for transmission only 43 h.p. is required, even if every tool is running; but it is found that in the average industrial shop every tool is not running at the same time, some being shut down and others operating on lower than maximum speeds, thus requiring less horse-power. It has

Digitized by Google

been determined practically that in the ordinary manufacturing establishment the mean effective power is but 30 per cent. of the total aggregate effective power which is required when all the tools are running at maximum load. This percentage is termed the load factor. In the case of belt-drive there is, then, 100 h.p. assumed loss for 100 h.p. effective load; that is, an efficiency of 50 per cent. Applying the load factor as above, it is found that there is but 30 mean h.p. to use and that it requires 100 h.p. to transmit it, thus giving the real efficiency as only 23 per cent, With the individual motor drive the loss varies with the load, Taking the same load factor, and assuming 30 per cent. as representing the loss incurred by the 30 h.p. effective load, there is but 9 h.p. loss against 100 h.p. with the belt drive. Thus, with individual drive, there is generated 39 h.p., of which 30 is effective, giving an efficiency of 77 per cent. against 23 per cent. by the shafting and belting method."

FIG. 6. Portable Drill Press.

2. *Cost of Buildings.*—Heavy overhead shafting is not required for the electric drive, hence the buildings may be made lighter and cheaper in construction, as settlingwill not throw parts of the equipment out of alignment and cause serious friction losses, vibration, etc.

3. *Cost of Equipment.* — The relative expense of equipping a factory with electric motors or with belting and shafting is usually greater in the former case, so that the saving in operation expenses, or increased earning power must more than offset the increased interest and depreciation. On the other hand the lower cost of the lighter building construction balances more or less the cost of the motors.

4. *Arrangement of Machinery.* — The use of electric motors enables the machinery to be placed in almost any desired position. It is not necessary that they should be parallel or arranged in rows, or placed at any particular angle with each other, whereas for belting and shafting the machinery must be arranged in a very particular manner, and very often it has to be placed where the light is poor, or accessibility and other important features must be

Digitized by Google

sacrificed. A great advantage obtained due to the flexibility of the electrically driven machines is that portable equipments are easily made up and operated, so that the tool is frequently brought

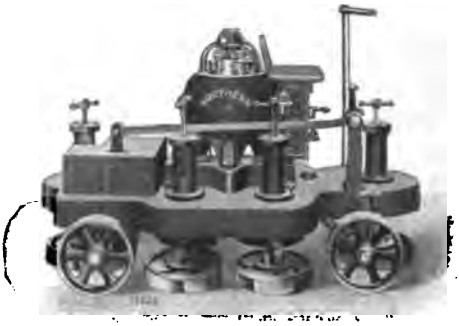


FIG. 7. Movable Floor-Surfaces.

to the object to be worked on, in place of bringing the work to the tool. (Figs. 6 and 7.)

5. *Clear Head Room.* — The elimination of overhead belting and shafting through the use of motors gives a clear head room, which enables overhead cranes to be freely used; a fact which results in a great saving of time and labor in the bringing of the work to the tools or removing finished pieces, the value of which is apparent when one considers the time and labor necessary to bar along heavy machinery on rollers. The clear head room also gives better illumination and ventilation. In fact the saving in cost for proper illumination may amount to as much or even more than the saving in tool operating power; since general illumination may be largely resorted to. Fig. 8 shows the appearance of a machine shop operated by belting and shafting, and Fig. 9 is an illustration of a plant where the tools are operated electrically, the great advantages regarding head room and illumination being well brought out by these two examples.

6. *Cleanliness.* — The dripping of oil from overhead shafting is a constant source of annoyance, and the dirt thrown out from belting is an even worse enemy to cleanliness. The agitation of dust by belting and shafting keeps it in constant circulation, so that it penetrates everything and everywhere. This is a very important matter in printing and textile work.

Digitized by Google

7. *Health of Employees.* — On account of the better ventilation and illumination, and reduction in dust and dirt, it is shown by actual experience that the general health of those who work with electrically driven machinery is improved. In the Government

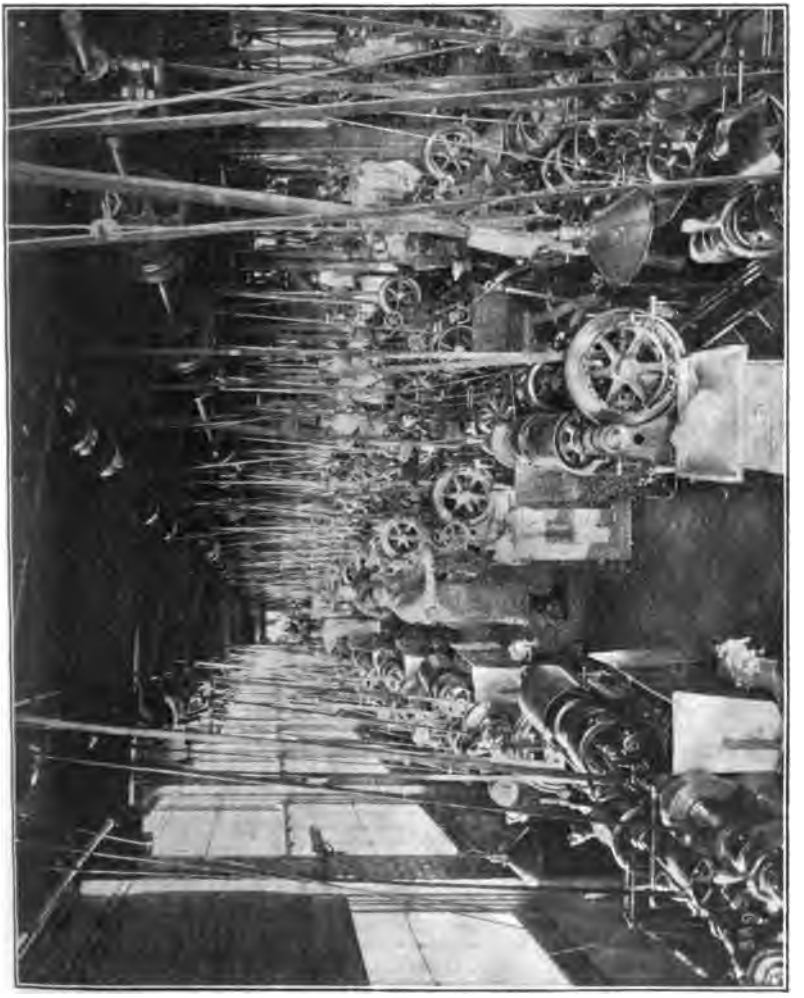


FIG. 8. An example of a great investment in shafts, pulleys and belts. A loss of power in transmission amounting to over 60 per cent.

printing office at Washington, it was found that the sick list was decreased about 20 to 40 per cent. after the electric drive was introduced.

8. *Convenience for Detached Buildings.* — The electrical method enables power to be supplied easily and economically to detached

Digitized by Google

buildings or sections, which is not possible with belt or steam transmission; therefore, the buildings, like the machinery within them, can be located for general convenience, and not with special regard to supplying them with power. This subdivision of a plant or

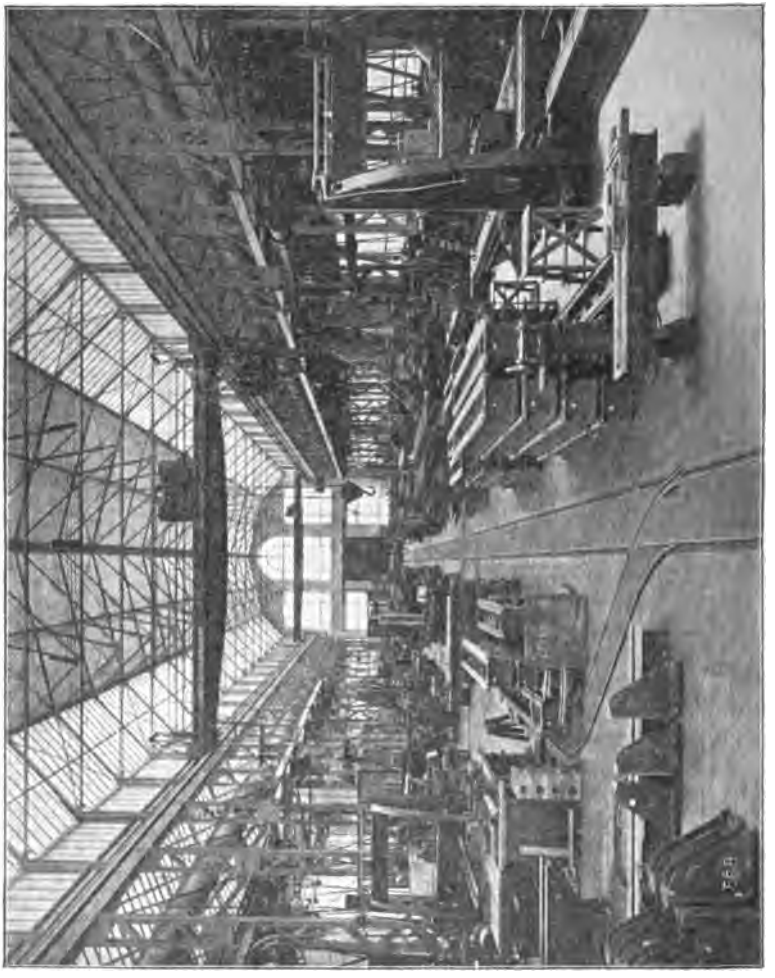


FIG. 9. Electrically Driven. No belts, shafting or pulleys. Allows a clear headway for crane service; a more convenient and economical arrangement of machines, and better lighting.

manufacturing establishment into a series of detached buildings is an almost absolute safeguard against total destruction by fire; and is thus a practical guarantee of continuous earning powers. If however electric power were not employed, it would be necessary to have long belting systems, involving great losses,

Digitized by Google

and extra heavy wall construction, or a series of small power plants calling for a larger force of men; and considerably less economical in operation than one central power house.

9. *Freedom for Growth.* — For similar reasons, with electric drive it is a simple matter to extend a building, or add another in any direction, whereas with belting, the shafting must be installed originally large enough to allow for extension; or else it must be replaced later; in which case the operation of the existing line shafts would be interfered with.

10. *Shut downs Less Frequent and Less Serious.* — An accident in an electrically driven plant usually has a local effect only, simply shutting down one or a few machines, while with belting and shafting the breaking or slipping off of a belt, or the failure of a friction clutch, may require the shutting-down of a whole plant or a large section thereof. In a large establishment a delay of even a few minutes represents a considerable item in wages, and in addition the interruption of the work is demoralizing. It might be argued that the central station may break down; this is however just as likely to happen with one form of power transmission as another.

11. *Speed Control.* — The variation of speed that is possible with the electric drive, and the convenience as well as the wide ranges o control, are great advantages with most kinds of machine work. The operator can drive the tool to its limit of capacity, and can, on the other hand, instantly relieve it of strain. With mechanical drive the methods of speed control are more limited and require more time to operate than with electric motors. The shifting of the belt on a cone pulley, or the throwing in and out of different sets of gears, takes more effort than the simple turning of a controller handle, which can be placed right at the work, and is thus not so likely to be carried out by the operator to gain slightly in the efficiency or rapidity of his work. The curves given in Fig. 10 show the time required to perform a certain piece of machine work, the speed control being by electrical and mechanical means, The cutting speed in the case of the electric drive being kept absolutely constant and at its maximum value throughout the operation, whereas that of the mechanical drive could not be adjusted as closely as this, but had to vary between control values. The saving in time thus obtained is considerable and correspondingly reduces the shop cost of the article.

Digitized by Google

12. *Increased Output.* — Owing to its many advantages, but especially on account of clear head room for crane service and convenient speed control, it is found that the output of manufacturing establishments is in most cases materially increased or the running expenses correspondingly decreased by the introduction of electric motor service.

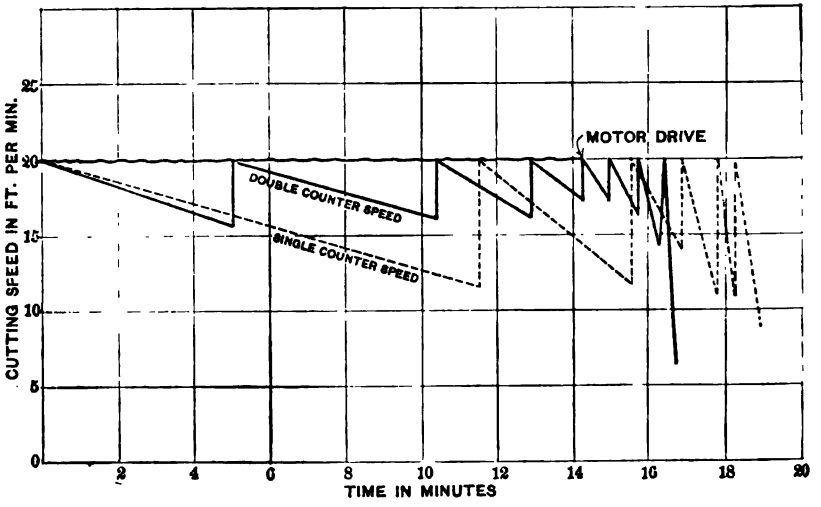


FIG. 10. Curves showing length of time required to perform certain machine work with electric and mechanical drive.

If a factory or a plant manager contemplates the substitution of electric drive for the ordinary mechanical drive, or other method o. power distribution, it would be advisable for him to study carefully the requirements of his work, so as to determine if variable speeds are necessary and what ranges, if individual or group drive would answer, and which type of motor is best suited for each tool or machine to be driven. He should then tabulate the advantages derived and give them their true monetary value; against these he should balance the interest on the additional expenditure, the maintenance and depreciation items. If then the result shows an annual saving which would amount to a sum of 5 per cent. or more of the cost of the new equipment, or the saving of a reasonable amount in the cost of his finished product, it would be a good policy for him to make the change.*

* The electrotypes for illustrations were loaned by the following companies: The Bullock Electric Mfg. Co., The Crocker-Wheeler Co., The General Electric Co., The Northern Electrical Mfg. Co.

Digitized by Google

ALUMNI AND UNIVERSITY NEWS.

SUMMER SCHOOL OF MINING.

A new departure was made this year in the conduct of the Summer School of Mining. Heretofore the class has always gone in one body to the mine or mines selected by the department and, in charge of from two to four instructors, according to the number of students, has done its work under constant supervision and advice. Last spring it was decided to divide the greater part of the class into small parties or squads, and send them without instructors to a number of different mining districts. To carry out this plan considerable correspondence was necessary in fixing upon mines suited to the purpose and in securing privileges and facilities for study. Through the liberality and kind coöperation of managers and superintendents, satisfactory arrangements were made at the following properties: Arizona Copper Co., Clifton, Ariz.; Daly West Mine, Park City, Utah; Tennessee Copper Co., Isabella, Tenn.; Baltic and neighboring copper mines, Houghton, Mich.; Penn Iron Mining Co., Norway, Mich.; Copper Queen Mining Co., Bisbee, Ariz. Twenty-one students, in six squads, elected to visit these mines; four squads of four men each, one of three men, and one of two. In addition, eight students made acceptable arrangements for themselves at various mines in or near Leadville, Ouray and Cripple Creek, Colo.; Butte, Mont., and Grass Valley, Cal.; also five students secured positions for the entire summer at mines in Tennessee, Michigan, Wisconsin, Colorado, and Arizona.

It was deemed advisable to retain the regular summer school in charge of instructors for such students as for any reason might prefer it. Arrangements were accordingly made at the Richard and Hurd iron mines, near Dover, N. J., and at several Pennsylvania anthracite collieries, in Luzerne Co., and the vicinity of Wilkes-Barre and Scranton. Seven students, constituting the remainder of the class, elected to attend this session, the work of which lasted from June 21 to August 3, inclusive, 4½ weeks being spent at the iron mines and 1½ week in the coal regions. The total number of students engaged in the summer mining work was 41.

Each student of the squads which did independent work was provided with a twenty-eight page printed outline of work, a vade mecum containing such detailed instructions as would enable any earnest student to do all that is required of those who attend the session under the care of instructors This pamphlet is an amplification of the brief printed scheme heretofore gotten out each year for the summer school classes. It contains notes and suggestions on: "Outfit for the Trip," "How to Take Notes and Make Sketches," "Hand and Machine Drilling," "Blasting, Stoping, Development and Method of Working," "Handling and Transporting Ore," "Mine Car, Cage, etc.," "Timbering," "Shaft Sinking," "Drainage and Pumps," "Ventilation and Lighting," "General Surface Plant," "Hoisting Engine," "Gallows Frame," "Compressors," "Boiler Plant," "Shops, Ore House and Pockets," "Handling Men and Organization," "Supplies and Material," "Geology and Ore Deposits," 'Milling and Concentration."

Digitized by Google

The change in the mode of conducting the summer school work was prompted by several considerations which have been impressed by experience upon those of the staff of the School of Mines who have had charge of the work for some years past. In making satisfactory arrangements for the summer school work difficulties are often encountered which naturally increase with the size of the class. The mere matter of securing suitable living accommodations in small mining camps not infrequently constitutes a problem in itself; and the embarrassment incident upon handling parties of students underground in such a way as to afford proper opportunity for observation and study, and yet not interfere with the mine work and incur criticism from the mine officials, may be serious when the numbers are large. It becomes necessary to divide the class into squads of two, or at most four, students, and distribute them in different parts of the workings. When the class is small the conditions are different. A sufficient number of suitable working places are readily found, so that a given party of miners would probably have but one squad of students stationed near them during the whole session. The miners are interested in the novel operations of note-taking and sketching, and are pleased to answer questions and offer suggestions. With small classes the total hindrance to the work of the mine becomes negligible. Evidently, a class consisting of but a single unit or squad — of say four students — would be most welcome to both manager and miner.

The question now suggests itself: what of the efficiency of the students' work under the new plan, without the oversight and assistance of instructors?

The writer has examined the note-books of the 34 students who were sent out this year without instructors and having to guide them only the printed outline of work above mentioned, together with such assistance as was given by officers and miners. He also spent about three weeks with the regular Summer School class, reading and criticising their note-books every night. As a result, it may be stated that the average work of the independent squads is at least equal to that of the regular class. Expressed more broadly, this summer's work, carried on under the new conditions, appears to be fully up to that of the past twelve years.

By the constant attendance of instructors in the Summer School work as usually organized, time is economized to some extent; the instructor acts as a cicerone to the best of his ability, shows the student how to carry on his work, and gives him specific information. The good students realize that they are working primarily for themselves and not for the School of Mines; all they require is the entrée to the mine and the privilege of studying it. But, on the other hand, the poorer students may come to depend too much on the instructor, whose presence tends to relieve them of a salutary feeling of personal responsibility for the quality of the work done. This matter, and the question of the real effect of the marking system, merit further consideration.

Though there are as yet insufficient data at hand to judge conclusively of the effect on the independent squads of absence of regular note-book criticism, it seems reasonable to infer that the inefficient students — some of whom are to be found in every class — lacking their daily gauge of quality, would be urged by fear of final failure to do better work

There is a saving of time under the system of daily instruction and guidance, in view of which a longer period of summer work is required

Digitized by Google

from the students of the separate squads. Notwithstanding the likelihood that mistakes will be made, it is quite possible that more deliberation and a slower speed of work will be found advantageous. Provided with valuable privileges, for the proper use of which they themselves are responsible, the students may be led to a more thoughtful habit of work, accompanied by the development of a spirit of investigation in keeping with university ideals.

Another consideration of a wholly different nature may be mentioned incidentally. When visiting the mines in small parties of three or four, the students have better opportunities to become personally acquainted with superintendents and foremen, and their chances are greatly increased of securing positions ready to be occupied immediately after graduation. An intelligent student could not fail to perceive that the quality of his work would be his recommendation.

DEPARTMENT OF CHEMISTRY.

General. — The course in chemical engineering, as outlined in the QUARTERLY for April, 1905, has gone into effect with the opening of the current term. Since only the first year was offered for 1905–6, it was necessary to refuse all applications for advanced standing in chemical engineering from graduates of other institutions or students in other courses of applied science. The number of such applications, together with the actual enrollment in the first year class, is very gratifying and shows the existence of a distinct demand for a course of this character.

Summer Session. — Attendance upon the chemistry courses in the summer session continues to increase. The registration in chemistry for 1905 was 156. A course on the principles of chemistry has been substituted for the teachers' course formerly given and courses in elementary organic chemistry, organic and sanitary analysis, and the chemistry of nutrition have been added.

Analytical Chemistry and Assaying. — Since the last publication of notes from these laboratories (November, 1903) Mr. M. A. Lamme has resigned as assistant to become tutor in mineralogy, and Mr. M J. Falk to enter commercial work. Mr. A. J. Mettler has been appointed assistant to succeed Mr. Falk.

Professor Miller has been promoted to a full professorship; Drs. Wells and Sherman to adjunct professorships; Mr. Cruser to the position of lecturer in qualitative analysis. Professor Wells was granted leave of absence for the year 1905–6.

Professor Miller has taken charge of qualitative analysis and has reorganized the system of instruction. The regular class is divided into six sections. Mr. Ellard, Dr. Beans and Mr. Cruser each instruct two of these, while Dr. Uhlig teaches a special section consisting chiefly of students entering with advanced standing. Dr. Beans has general supervision of the theoretical instruction and Mr. Ellard of the laboratory work. The method of instruction gives more time to recitations than formerly, and the division of the class is such that no section contain over forty students.

A room adjoining the industrial laboratory has been equipped for research work in analytical chemistry and provides suitable accommodations for two graduate students. Four candidates for the degree of Ph.D.,

Digitized by Google

taking thesis work with Professor Miller, are engaged respectively upon investigations of iodine titrations, the chromi-cyanides, the silver-platinum and silver-iridium alloys, and the double ferric phosphates.

The following investigations have been completed and published since the last notice in this QUARTERLY:

"The Reduction of Lead from Litharge in Preliminary Assays and the Advantages of an Oxide Slag." By E. H. Miller, E. J. Hall and M. J. Falk. *Trans. Amer. Inst. Min. Eng.*, 34, 387.

"The Influence of Diet, Muscular Exertion and Loss of Sleep upon the Formation of Uric Acid." By H. C. Sherman. *Jour. Am. Chem. Soc.*, 25, 1157.

"The Determination of Nitrogen in Food Materials and Physiological Products." By H. C. Sherman, C. B. McLaughlin and Emil Osterberg. *Jour. Am. Chem. Soc.*, 26, 367.

"The Determination of Molybdenum in Steel and in Steel-making Alloys." By F. V. D. Cruser and E. H. Miller. *Jour. Am. Chem. Soc.*, 26, 675.

"A New Separation of Thorium from Cerium, Lanthanum and Didymium by Metanitrobenzoic Acid." By A. C. Neish. *Jour. Am. Chem. Soc.*, 26, 780.

"A Crucible Charge for Gold and Silver in Zinc Ores." By E. J. Hall and E. Popper. SCHOOL OF MINES QUARTERLY, 25, 355.

"Changes in the Composition of some Ferrocyanides of Cadmium and Zinc after Precipitation." By E. H. Miller and M. J. Falk. *Jour. Am. Chem. Soc.*, 26, 952

"The Determination of Nitrogen in Organic Compounds." By H. C. Sherman and M. J. Falk. *Jour. Am. Chem. Soc.*, 26, 1469.

"The Application of Bismuth Ammonium Molybdate to Gravimetric Analysis." By E. H. Miller and F. V. D. Cruser. *Jour. Am. Chem. Soc.*, 27, 116.

"The Determination of Ammonia in Milk." By W. N. Berg and H. C. Sherman. *Jour. Am. Chem. Soc.* 27, 124.

"A Study of Methods for the Determination of Formaldehyde." By R. H. Williams. *Jour. Amer. Chem. Soc.*, 27, 595.

"The Influence of Atmospheric Oxidation upon the Analytical Constants of Fatty Oils"—Second Paper. By H. C. Sherman and M. J. Falk. *Jour. Am. Chem. Soc.*, 27, 605.

"Comparative Experiments upon Chemical Preservatives in Milk." By H. C. Sherman, A. W. Hahn and A. J. Mettler. *Jour. Am. Chem. Soc*, 27. 1060.

In addition to the above papers there have been published from the quantitative laboratory:

"An Index to the Literature of Thorium, 1817–1902." By C. H. Joüet. Smithsonian Miscellaneous Collections, No. 1374, in Vol. XLIV.

"Quantitative Analysis for Mining Engineers." By E. H. Miller. The Van Nostrand Co., 1904.

"The Calculations of Analytical Chemistry — Third Edition, Revised and Enlarged." By E. H. Miller. The Macmillan Co., 1905.

"Methods of Organic Analysis." By H. C. Sherman. The Macmillan Co., 1905.

Organic Chemistry. — During the past year, the following gifts have been received: From Kuttroff, Pickhardt & Co., two pounds of uranine,

Digitized by Google

for use in an investigation of the nitrofluoresceins; from Leerburger Bros., a sample of their Essence of Maple, one of their finest flavoring extracts; from Dr. Hugo Schweitzer, a set of samples illustrating the preparation of certain new dyestuffs; from Merck & Co., a beautiful set (43) of alkaloidal products for the Chemical Museum.

Of the students who were last year engaged in advanced work in the laboratory, Dr. Wright has gone to Washington and Jefferson College, as professor of chemistry; Mr. Owen is in charge of chemistry and physics at the Potsdam Normal School, at Potsdam, N. Y.; Mr. Dox is one of the chemical staff of the Storrs Agricultural Experiment Station, at Storrs, Conn.; Mr. Hoffman has gone to Berlin, for a year's study and research; and Mr. Renshaw, after serving during the summer as chemist for the Pine Products Co., has returned to Columbia to continue his investigations on 4-amino-o-phthalic acid.

Of the new research workers, one comes from the chemical staff of the Rose Polytechnic Institute, and one from that of Smith College; another is teaching chemistry at the De Witt Clinton High School, while a fourth occupies a similar position at the Mount Vernon High School. The total number of students in the laboratory is larger than ever before.

During the winter many papers were presented before the N. Y. Section of the American Chemical Society. At the thirty-second general meeting of the American Chemical Society, held at Buffalo, June 22–24, Professor Bogert delivered an address upon "The Classification of Carbon Compounds." He was also the Chairman of the Section of Organic Chemistry, before which he presented nine papers, embodying the results obtained in investigations recently conducted in the Organic Laboratory. These researches resulted in the discovery of nearly one hundred new compounds, among which the naphtotetrazines are especially worthy of mention, as they add an entirely new group of compounds to organic chemistry.

It has not been possible as yet to publish all the papers presented during the past year, but the following publications have appeared from the laboratory since the last report to the QUARTERLY:

1. "Review of American Chemical Research." By M. T. Bogert. *Jour. Am. Chem. Soc*, XXVI., R. 420–425 (Oct.), 449–456 (Nov.), 486–488 (Dec.); XXVII., R. 24–35 (Jan.), 89–95 (Feb.), 132–150 (Mar.), 220–225 (April), 266–272 (May), 340–343 (June), 402–414 (July), 470–479 (Aug.), 510–516 (Sept.), 562–565 (Oct.).

2. Review of Lassar-Cohn's "Application of Some General Reactions to Investigations in Organic Chemistry" (translation by J. Bishop Tingle). By M. T. Bogert. *Jour. Am. Chem. Soc.*, XXVII., 83–84 (Jan.).

3. Review of Schreiner's "The Sesquiterpenes." By M. T. Bogert. *Jour. Am. Chem. Soc.*, XXVII., 638–639 (May).

4. A card index stock list for use in university departments of organic chemistry. By M. T. Bogert. *Science*, N. S., XXI., 750–752 (May).

5. "The Synthesis of 5-nitro-4-ketodihydroquinazolines from 6-nitro-2-aminobenzoic Acid, 6-nitro-2-acetylaminobenzoic Acid, and from the Corresponding Nitroacetylanthranil." By M. T. Bogert and V. J. Chambers. *Jour. Am. Chem. Soc.*, XXVII., 649–658 (June).

6. Review of Raphael Meldola's "The Chemical Synthesis of Vital Products, and the Interrelations Between Organic Compounds." By M. T. Bogert. *Jour. Am. Chem. Soc.*, XXVII., 793–795 (June).

Digitized by Google

7. "The Condensation of Succinylosuccinic Acid Diethyl Ester with Guanidine. A Derivative of 1,3,5,7-naphtotetrazine, a New Heterocycle." By M. T. Bogert and A. W. Dox. *Jour. Am. Chem Soc.*, XXVII., 1127–1140 (Sept.).

8. "Some Acyl Derivatives of Homoanthranilic Nitrile, and the 7-methyl-4-ketodihydroquinazolines Prepared Therefrom." By M. T. Bogert and A. Hoffman. *Jour. Am. Chem. Soc.*, XXVII., 1293–1301 (Oct.).

9. "The Condensation of Succinylosuccinic Acid Diethyl Ester with Acetamidine: 2,6-dimethyl-4,8-dihydroxy-1,3,5,7-naphtotetrazine." By M. T. Bogert and A. W. Dox. *Jour. Am. Chem. Soc.*, XXVII., 1302–1305 (Oct.).

10. "The Synthesis of 2-methyl-5-nitro 4-ketodihydroquinazolines from 6-nitroacetanthranil and Primary Amines." By M. T. Bogert and H. A. Seil. *Jour. Am. Chem. Soc.*, XXVII., 1305–1310 (Oct.).

11. "Some Experiments on the Nitro Derivatives of Fluorescein." By M. T. Bogert and R. G. Wright. *Jour. Am. Chem. Soc.*, XXVII., 1310–1316 (Oct.).

12. "The Synthesis of 7-nitro-2 alkyl-4-ketodihydroquinazolines from 4 nitroacetanthranilic Acid, and from 4-nitroacetanthranil." By M. T. Bogert and S. H. Steiner. *Jour. Am. Chem. Soc.*, XXVII., 1327–1331 (Oct.).

13. Review of Leffmann and La Wall's "Text-book of Organic Chemistry." By V. J. Chambers. SCHOOL OF MINES QUARTERLY, XXVI., 428 (July).

14. "Constitution of Quinine." By B. L Murray. SCHOOL OF MINES QUARTERLY (see this number); also Merck's Report, XIV., 237–239 (Aug.), 267–268 (Sept.), 301–302 (Oct.).

Physical Chemistry. — The adjunct professorship of physical chemistry, which was first filled in 1901, has been raised during the past year to a full professorship.

Mr. C. W. Kanolt (B. S., Columbia, 1902) has just fulfilled the requirements for the degree of doctor of philosophy in physical chemistry which has been conferred upon him, and as Barnard Feilow, is continuing his studies under Professor Nernst at the University of Berlin. Although as yet Mr. Kanolt's dissertation "The Combination of a Solvent with the Ions" (Contributions from the Havemeyer Laboratories No. 114) has only been published separately; it will shortly appear in a well known journal.

Mr. M. F. Coolbaugh (B. S., Colorado College) received the degree of master of arts last June, his thesis being the result of work upon the electrolytic deposition of alloys. Although Mr. Coolbaugh intended to continue his research for the degree of doctor of philosophy, his acceptance of the professorship of chemistry in the South Dakota School of Mines has prevented his return to Columbia this year. He is at present working there, however, under the direction of Professor Morgan, and expects to return to Columbia at a later time to fulfill all the requirements for the degree of doctor of philosophy.

The third revised and enlarged edition of Professor Morgan's "Elements of Physical Chemistry" has just been published by Messrs. John Wiley & Sons, and is serving as a basis for the lectures in Chemistry 4 and Chemistry 37. Another work by the same author, "Physical

Digitized by Google

Chemistry for Electrical Engineers" is now in press and will probably appear before Christmas. This book is especially intended for use in Chemistry 37, and is taken up from the purely experimental, *i. e.*, non-hypothetical standpoint. This avoidance of all hypotheses has been advocated for some time by Ostwald, who has written an elementary chemistry from this point of view, but this is the first work attempting to perform a like service in the more advanced branches of chemistry.

Laboratory of Industrial Chemistry. — Many changes have been made in this laboratory since the beginning of the term, owing to the establishment of the new laboratory of electro-chemistry in the basement of Havemeyer Hall.

Room 415 H, formerly occupied by the large electric furnaces, has been changed into a research room, much to the advantage of the whole laboratory, as regards noise and dust, and is at present occupied by Messrs. John F. Thompson and Louis Cohen, studying for Ph.D. degrees under Professor Miller.

Room 420 H, formerly the electromechanical laboratory, has been remodeled and serves as a very convenient laboratory for chemical microscopy, Chemistry 34.

Professor Pellew, who this year is taking personal charge of Chemistry 26, as well as 10, 27 and 34, is assisted by Mr. Glenn H. Pickard, '04, School of Chemistry.

The course in inorganic preparations, Chemistry 26, has been entirely remodeled, and each student after making three or four routine preparations, is required to make at least one preparation of an absolutely chemically pure compound, preferably one which he is likely to meet and have use for in his future work; and, before completing the course, is required to make one or more preparations, requiring both skill and research, of salts of some of the rare elements.

Researches are in progress, or in preparation, upon varnishes, silk analysis, and microchemical analysis.

DEPARTMENT OF CIVIL ENGINEERING.

The department of Civil Engineering has begun the work of the academic year with a highly prosperous Summer School of Surveying at Morris, Conn., in the new buildings which add much to its efficiency and comfort. The remaining two buildings required to complete the entire plant of the school are now in process of construction and will be completed before the end of the autumn.

The removal of the School of Mines into the new mining building has afforded opportunity for a greatly needed development of class room and museum space for the Department of Civil Engineering. These conditions have also made it feasible to install a departmental library containing a large amount of civil engineering plans and documents hitherto necessarily so imperfectly cared for as to be essentially unavailable for any useful purpose. A considerable quantity of both engineering documents and plans have been added to the department besides a most generous gift of a number of water meters from the National Meter Company. Material additions have also been made to the apparatus of the cement and road materials-testing laboratories. Some substantial developments have also been made in the administration of the practical work of the department.

Digitized by Google

Mr. C. E. Morrison has been made assistant in civil engineering in place of Mr. J. A. Coelos, who at the end of last year discontinued his connection with the university to go into active practice. There have been no other changes in the teaching staff.

DEPARTMENT OF ELECTRICAL ENGINEERING.

Mr. Fitzhugh Townsend was appointed instructor, commencing the first of July, having been the tutor in the department for five years.

C. A. Schneider, electrical engineer, 1904, has been appointed, October 23, assistant in the department in charge of the direct current laboratory.

Professor Crocker has been appointed the chairman of the Committee on Standardization of the American Institute of Electrical Engineers, and one of his main efforts will be to rearrange in logical order the National Electric Code now used by all insurance and electrical interests in the installation and manufacture of electrical appliances.

The department is fitting up Room No. 502 Engineering as a fourth year draughting room as an adjunct of the department which has been greatly needed for some years.

There have been received during the summer some field rheostats from Mr. D. J. Burns, electrical engineer, 1900, of the Ward Leonard Electric Company, Bronxville, New York; a complete telautograph apparatus, as a loan from Mr. James Dixon, electrial engineer, 1901, Engineer of the Gray National Telautograph Company; one thousand feet of insulated cable from the safety Insulated Wire & Cable Company through the kindness of graduates in the electrical department, and one electric storage battery cell through the courtesy of the Electric Storage Battery Company of Philadelphia.

Professor George F. Sever was appointed July 1 by the President, as acting-dean of the Faculty of Applied Science, until the selection of a permanent dean. He resigned as secretary of the faculty October 27.

During the summer, the direct and alternating current laboratories have been entirely overhauled and put in excellent operative condition. Some new transformers and supplies have been secured, and an important addition has been gained through the kindness of Mr. G. B. Rosenblatt, electrical engineer, 1902, of a 10,000 volt-testing transformer of 5 K. W. capacity so arranged that any voltage from 2,500 to 10,000 at full capacity of the transformer can be secured.

Digitized by Google

BOOK REVIEWS.

Pyrite Smelting. Edited by T. A. RICKARD. New York, The Engineering and Mining Journal, 1905, pp. 306. Price, $2.00.

Mining engineers and metallurgists will appreciate this publication in book form of the extended discussion on pyrite smelting, which took shape in numerous articles and letters printed in the *Engineering and Mining Journal*, from October, 1903, to February, 1905.

The range of the subject matter is indicated by the following ten questions, which were sent out by the editor and elicited the discussion: (1) What types of ore are suited to the process (direct smelting of pyritic ores)? (2) Is hot blast advisable? (3) To what extent can fuel be eliminated? (4) What amount of copper is required for the collection of the precious metals? (5) What percentage of lime is necessary to a clean slag? (6) What percentage of zinc in the charge can be treated profitably? (7) What is the degree of desulphurization attainable? (8) What are the possibilities as to capacity of furnace? (9) What are the limitations of the process? (10) What is the relative economy as compared with rival processes?

Among those who replied to the questions are many prominent members of the profession, and a great deal of valuable information bearing on this increasingly important branch of metallurgy has been made conveniently available in the present volume The most important single contribution is by Dr. E. D. Peters. It was written in 1904, at the request of Mr. Rickard, after the discussion had been in progress some seven months, and takes the form of a review. First is given a concise tabulation, embodying the gist of the replies received from the other contributors. A marked unanimity of opinion is shown as to most of the points — or at least but little actual conflict. Such differences as exist are attributed mainly to variations in the character of ores treated and the conditions under which each writer had gained his experience in pyritic smelting. Dr. Peters then devotes some fifty pages to more detailed comments and comparisons, and finally presents a summary of results. A number of papers by other metallurgists follow, which, though not referring specifically to the original questions propounded, contain much useful testimony as to the various phases of the subject. Among the most interesting of these are the papers by Messrs. John Parke Channing and Herbert Lang.

The book closes with three chapters on: "Smelting at Mt. Lyell, Tasmania," the material for which was prepared by the members of the staff of the Mt. Lyell Mining and Railway Co.; "Reverberatory Copper Smelting at Anaconda," by E. P. Mathewson, and "The Matting of Ores at Leadville and Robinson, Colorado," by C. H. Doolittle.

It may be noted here that, after some consideration, the editor has adopted the term, "Pyrite Smelting," instead of the older form, "Pyritic Smelting," as being a more accurate designation for the operation of direct smelting of sulphide ores. R. P.

Digitized by Google

The Copper Mines of Lake Superior. By T. A. RICKARD. New York, Tne Engineering and Mining Journal, 1905, pp. 162, 49 ills. Price, $1.00.

This brief but very readable description of the Lake Superior copper district is the result of a trip made by Mr. Rickard to the Keweenaw Peninsula in 1904. The series of articles written at the time for the *Engineering and Mining Journal* have been revised and somewhat amplified for publication in book form.

In the concise and vigorous style, which has left its impress on the editorial pages of the *Journal* during the past few years, the author presents a sketch of the local geology and modes of occurrence of the copper in the great conglomerate and amygdaloidal veins; reviews the history of the district and of the discovery and vicissitudes of a number of the individual properties; describes and compares the methods of mining and milling employed at some of the prominent mines, together with the smelting practice, as illus rated in two establishments, one old and the other but recently completed, and gives an interesting account of the the occurrence of "mass" copper.

The book evidently is not intended to be purely technical. It is addressed to all who are interested in, or connected with, the development of the mineral resources of the country.

In the preface the author refers pointedly and at some length to his failure to obtain admittance underground at either the Calumet and Heckla or Tamarack mines. The reader will share his plainly expressed disappointment on finding only passing references to these two important properties. Some degree of liberality, on the part of those in control, in permitting publication of such technical data as may with propriety be given to the mining world, would be more in keeping with the growing tendency elsewhere to a freer interchange of professional information.

R. P.

Cements, Limes and Plasters; their Materials, Manufacture and Properties. By EDWIN C. ECKEL, C. E., Associate, Am. Soc. C. E.; Member, Soc. Chem. Industry; Asst Geologist, U S. Geol. Survey. New York, John Wiley & Sons, 1905. Pp. xxxiv + 712. 165 ills., 254 tables.

The author divides the subject into seven parts, viz: "Plasters," "Limes," "Magnesia and Oxychloride Cements," "Hydraulic Limes," "Natural Cements," "Portland Cement" and "Puzzolan Cements." He begins with a general classification of cementing materials and then takes up under each head the composition, properties and derivation of raw materials, together with the methods of making and testing the limes and various types of cement.

While this statement gives some notion of the ground covered by Mr. Eckel's important treatise, an adequate idea of the amount of research in the extensive literature of the subject, together with study and investigation in the field, required to present fully so large a subject, can be gained only by a careful examination of the work itself.

In endeavoring to keep the size of the book within reasonable limits, the author has found it impracticable to discuss in full detail all branches of the subject. As he himself remarks, some points of interest are only suggested. But, appended to nearly every chapter is a bibliography,

Digitized by Google

comprising such references (chiefly to American technical journals) as will enable the reader to pursue further study in any of the topics treated.

The book is intended for the working engineer and the intelligent contractor. It is eminently practical. Much attention is devoted to questions of labor, power and costs. For example, detailed estimates are given of costs of lime burning, with a valuable table of the elements of cost, expressed in percentages of the total. The discussion of the raw materials, composition, manufacture, properties, and specifications of natural cements occupies ninety pages. In recognition of the importance of Portland cement manufacture as an industry, and of its wide use as a building material, the author devotes to it 335 pages of thorough critical description, accompanied by copious lists of references. Such matters as the calculation and preparation of the Portland mixtures for the kiln (pp. 382 to 428) are presented in great detail. The descriptions of the crushing and pulverizing machinery are also satisfactory.

In all parts of the book tabulations and diagrams are freely used to shorten verbal descriptions. The illustrations are abundant and generally good, many being reductions of working drawings, with the principal dimensions. A clear and concise style is not one of the least attractions of the work. The printing is well done and there is a good index of twenty pages.

As hinted by the author in his preface, enough time has been devoted to the study of the subject, and the actual writing of the book, to make the statements reliable and authoritative. R. P.

Cement and Concrete. By LOUIS CARLTON SABIN, B. S., C. E., Assistant Engineer, Engineer Department, U. S. Army; member of Am. Soc. of Civil Engineers. New York, McGraw Publishing Co., 1905.

This book covers the subjects of cement and concrete from an engineering standpoint in an efficient manner, sufficiently thorough for the ordinary uses of the engineer and engineering student. The results of tests given were obtained during the construction of a large and important work and should be reliable. Part I. takes up the "Classification and Manufacture"; Part II., "The Properties of Cement and Methods of Testing"; Part III., "The Preparation and Properties of Mortar and Concrete"; Part IV., "Use of Mortar and Concrete." In Part IV., is found a chapter on reinforced concrete which gives the formulas for strength of beams and a collection of tests of the strength of concrete steel beams, which are of great practical value to the engineer. S. O. M.

American Telephone Practice. By KEMPSTER B. MILLER. Fourth Edition. New York, McGraw Publishing Co. 881 pages, 643 illustrations.

This edition, while still somewhat vague in the consideration of inductance and capacity, is a great improvement on the former editions. The book is particularly good in the treatment of the "Common-battery Exchange Systems," and in the discussion of "Automatic Telephone Exchanges." The illustrations are good, and the scheme of drawing the axial portions of the common battery exchange diagrams with heavy lines is excellent. Taken as a whole, the book is a valuable addition to the literature on telephone practice, and should be useful to the student and telephone engineer. M. A,

Digitized by Google

High Tension Power Transmission. A republication of the work of the Transmission Committees 1902–1904, of the American Inst. of Electrical Engineers, by The McGraw Publishing Co., New York.

This work is in the main part a presentation of the opinions of the leading experts in high tension transmission, and indicates the facts to be considered in the standardization of such equipments. While the same matter appears in the *Transactions* of the American Inst. of Elect. Engs. for 1903 and 1904; the form in which it is given in this republication, and the complete index of the contents of the book make it a valuable addition to the reference books on electrical engineering practice, and one which should be appreciated by the profession.

M. A.

Digitized by Google

THE

SCHOOL OF MINES QUARTERLY.

VOL. XXVII. JANUARY, 1906. No. 2.

THE HISTORICAL DEVELOPMENT OF GENERAL CHEMISTRY.*

BY WILHELM OSTWALD,

PROFESSOR AT THE UNIVERSITY OF LEIPZIG.

FIRST LECTURE. ELEMENTS AND COMPOUNDS.

Ladies and Gentlemen: The task I have undertaken for to-day and the following days is to give you a sketch of the scientific development of chemistry, and of the history of the leading ideas in their broadest generalization.

Chemistry is a very large science indeed. You remember possibly one or two years ago there was celebrated the day of the coming into existence of the 50,000th compound in organic chemistry; this shows at once how large chemistry is, for besides these 50,000 compounds of organic chemistry there are the inorganic compounds which have not been counted as yet.

To get a comprehensive view of such a vast body we will make use of a method which is in vogue with biologists, to investigate complicated organisms. It is known as the cross-section method. This method consists in cutting through the organisms parallel cross-sections from side to side, and investigating and comparing them; by such comparison of these different cross-sections they get a comprehensive view of the whole organisms. In this

*Course of six lectures delivered in the Department of Chemistry of Columbia University, in Havemeyer Hall, January 26 to February 2, 1906. Reported stenographically.

Copyrighted by SCHOOL OF MINES QUARTERLY.

Digitized by Google

way we are going to cut different cross-sections through the whole body of chemistry. In every case we will investigate the development of a certain set of ideas and changes from the first beginnings which we know of, down to their latest development in our times, and in this way I hope to present to you some plastic views of the whole science of general chemistry.

As to the first cross-section: We shall investigate to-day what lies at the very bottom of every chemical investigation.—It is the question of the chemical elements; the difference between elements and compounds. This is the framework in which every chemical fact finds later its place in properly arranged sequence.

Now the first stages of every development always seem to us rather absurd. It is the same with the question of chemical elements. The peripatetical elements, as they have been called and as they have been maintained through many centuries, were first invented by Aristotle. Aristotle after examining the possible properties of different bodies and their changes, reached the idea that every body should be possessed of at least one of the following properties: It should be either dry or wet; and it should be either warm or cold. Why Aristotle selected just these properties it is impossible to tell now. They probably seemed the best to his systematic mind, and so he arranged the following scheme:

Wet

Cold Hot

Dry

Although these four things can be combined in six different ways, but two of these possible combinations will not do, because a body can not be at the same time wet and dry, or hot and cold, and therefore only four combinations remain between wet and cold, and cold and dry, and dry and hot, and wet and hot. These are the four elements of Aristotle. Something which is cold and wet is comparable to water, and therefore water is one element. A thing which is wet and hot is comparable to air, and therefore air is another element; and something which is dry and hot at the same time would be fire; and something which is cold and dry at the same time is earth. Now we have here the four ancient elements, and these elements were considered as the true elements of every kind of matter through a long series of years.

This may have been satisfactory to a philosophical mind, but it

Digitized by Google

did not prove satisfactory to the chemists who were busy investigating the different substances and the possibilities of their changes. Chemistry has developed, as every science has, from practical questions; from the questions of dye manufacturing, metal manufacturing, the manufacturing of chemical compounds, etc., and slowly all this scattered knowledge was brought into order and arranged to constitute the science of chemistry.

Now, this knowledge of chemical changes and chemical preparations did not fit very well into the beautiful scheme of Aristotle's, and therefore the chemists tried to discover some system which would fit better with their practical experience. They found that the different substances could be arranged in certain classes in such a way that every body could be put into one of these classes, and as types or heads of these classes they selected, first, *sulphur*, to explain or describe the possibility of burning or combustibility; then they made the class of *mercury* to describe the metallic properties; then the class of *salts*, for substances which are soluble in water and have a distinct effect on the taste; and at last there were substances which did not possess any of these properties which did not affect the taste, were not soluble in water, did not show a metallic lustre and were not combustible. These substances were put into the class of *earths*, therefore earth was the only class which remained from the old Aristotle scheme.

You see at once that this distinction or classification was much more practical than that of the old philosopher, but it was still rather imperfect. It is a most general fact in the psychology of science that even if an old and habitual view proves to be quite erroneous, the correction of such a view is never an absolute or radical one. People try rather to correct only in a somewhat superficial way the worst part of the old view, to retain as much as possible of it. Therefore there remains in every case, even after a practical correction, some absurdity from the older view in the newer one, or some unjustifiable assumption. And so it was also with these elements of sulphur, metals, earths and salts. For they assumed tacitly the same thing that Aristotle has assumed in making his definitions, that matter was in truth something inert and devoid of properties and that this inert matter could be endowed with different properties at will. They assumed that these properties could be taken away from one piece of matter and given to another piece of matter; in fact the general view of

Digitized by Google

matter and properties was that both behaved like a man and his clothes; he could put on whichever clothes he chose and change them according to his will. The elements were considered not as matter but rather as properties to be connected with inert matter.

There is, of course, some truth in this idea. We can heat any body; *i. e.*, endow any piece of matter with the property of a certain temperature, and can change this property at will. We can electrify a piece of metal, and then take away the electricity; and this process is even quicker than that with heat. Therefore this view that matter is inert and is not endowed with properties is an extrapolation from certain real facts, but sophisticated by a number of assumptions which are not facts at all and which have never been proved.

So also chemists assumed that indeed any piece of matter can be endowed with any property and this general assumption explains the investigations of the alchemists, or the chemists who tried to change the base metals into gold. Generally we assume it was absurd to attempt this, and we know indeed that the alchemists did not succeed in their trials. But from their scientific standpoint it was a logical and justifiable investigation to seek some process by which, for example, lead could be turned into gold. A number of processes were known by which one substance could be changed into another substance with quite different properties, and there was no general law known which prevented the changing of lead, copper or silver into gold just as mercury could be changed into cinnabar, or cinnabar into mercury. It was only the discovery of a much later date that this change was impossible and that quite a number of other changes are impossible in a similar way, just as it is impossible to get, for example, from an iron ore any other metal than iron, or to invent any other process by which a derivative of lead can be changed to mercury, or tin, or some other metal which is not lead.

It took, indeed, a long development to reach the consciousness of these facts and it was not until about two centuries ago that a general law connecting these facts was recognized, viz., that every substance is associated, so to say, with only a definite number of other substances which can be made from this substance, and that these possibilities are distinctly limited in such a way that only a certain range of substances can be derived from a certain starting point, and that only from these derivatives can the primary substances be recovered.

Digitized by Google

It took, indeed, a very long time to arrive at a clear idea of this fact, although many individual facts in this line had been already discovered. Of course the producers of metals knew exactly the ores which gave copper, brass or iron, they could distinguish these different ores from each other, and knew that there was no possibility of changing the product of one ore into the product of another. But these were only single instances of this general law I have already tried to express, while the law itself remained unknown.*

But the man who recognized the general law connecting all these single facts was Robert Boyle. Boyle plainly and distinctly pointed out that it is useless to assume any philosophical elements. We should only cling to experience and call elements substances which are distinguished by properties of their own and which can be changed into compound substances by combination with other elements. In this way we owe to Boyle the first real definition of an element. Of course it was still rather incomplete from our modern standpoint, but he first pointed out the real meaning of an element, it was no longer a *property* of matter but a certain *kind* of matter.

To get a clearer idea of the conception of an element, we have to investigate another subject, still broader in its application. The concept of a *chemical substance*, or a *chemical individual* as we shall call it. We find in nature quite a number of different substances, *e. g.*, ores and minerals which are endowed with certain properties, as color, lustre, specific gravity, etc., we find again that each substance can be found in different places or produced artificially in different ways, and yet shows in every case, no matter where found, or in what way produced, exactly the same properties. Sulphur, for example, is sulphur, irrespective of the way we get it. Whether found in nature or made by a chemical process, we always find it a yellow substance, non-conductive of electricity, and burning with a pale blue flame, etc. In this way Boyle claimed also that we should distinguish different substances according to

*An example of a rather complete instance of this law is given in the book of Basilius Valentines, "Der Triumpwagen des Antimoni." Although this work is now considered to be a counterfeit of a later date, it shows still in a very perfect way the point in question. It deals with the derivatives of one substance: *Antimony.* All these different substances are endowed with the property of changing back into antimony again under proper circumstances, and in this book about antimony we have the first monograph of the derivatives of a given element.

Digitized by Google

the properties they possess. We find, then, that every substance is a species of its own, just as dogs and horses and bats, etc., are species of their own, and that although the different individuals of the same species may present slight differences in their properties, they always maintain similarity. How is this with chemical species?

If we compare, for example, different samples of water; we find that all water is substantially the same, freezing at zero, and boiling at 100 degrees centigrade, and colorless. But if we investigate them more closely we find them slightly different. Water from a well will have a different taste from water from a river or water from the sea, and when we determine carefully the boiling point, we find that sea water shows a little higher boiling point than river water, and also that the freezing point of sea water is a little lower than the freezing point of river water. Therefore it was assumed (tacitly, indeed, for I have not been able to find any distinct statements) that different specimens of a given substance could show slight differences in properties just as two dogs are not quite alike, although having a large number of similar properties; one dog may be black and another white; one small and another large; yet all are dogs. In the same way water may be fresh, well water, or salt, sea water, both endowed with similar properties, yet slightly different upon closer inspection. But slowly it became apparent that this comparison was misleading. The chemists learned to purify their substances, to get, for example, from these different samples of water, by a very simple process, distillation, water with identical properties. The distilled water obtained from sea water and from river water, etc., showed exactly the same boiling point, the same freezing point and the same density; all the properties which could be investigated turned out to be of the same value. Slowly, without any distinct expression of these discoveries in the history of science, the idea developed that chemical substances, or chemical individuals are not comparable with the species of animals or plants but different from them as to the complete identity of the properties of the single example.

Therefore, a chemical individual is defined or described as a substance which is endowed with certain distinct properties and these properties are the same and not dependent upon the way in which these substances have been produced or found.

This is a most important development, but I must repeat, it is impossible to trace the historical line of this development; it was too slow a process.

Digitized by Google

In this way we come to the end of the eighteen h century when the very slow progress of chemistry in former times changed into quite a rapid one, and finally to the tremendous rate of scientific development which characterized the end of the nineteenth century. This development is marked in our cross-section by the change in one general view in chemistry brought about by the discovery of oxygen, and the elimination of the theory of phlogiston, as a result of the general law of the conservation of weight in chemical changes.

The general chemical facts which we call oxidation and reduction in our times, were recognized and brought into scientific comprehension during the eighteenth century. It was known, for example, that just the same substance which is formed by the burning of charcoal in the air could be formed by mixing the charcoal with certain substances, litharge, for example, and heating the mixture; the litharge would be reduced to metallic lead and the charcoal would disappear, just as it disappeared in burning in air. On the other hand, metallic lead would be changed into litharge by heating it in contact with air. In a similar way different substances could be burned and then brought back to their former condition by heating them with a more combustible substance. In such a way the general idea of reduction and oxidation was formed long before oxygen as a substance by itself was known. To get a comprehensive view of all these facts the theory of phlogiston was invented. According to this the change of properties and the evolution of light and of heat during combustion were all connected with the existence of a certain element called phlogiston. If a substance burned, a flame generally appeared, and it was assumed that phlogiston passed away from the substance during combustion. Then it was assumed that in the process of reduction the former properties were restored to this substance by uniting it with phlogiston. This gave quite a comprehensive theory of combustion, as you are aware, with one false assumption.

Instead of assuming that the product of combustion is the result, as we now know, of an addition of oxygen to some element, it was assumed that something, namely, phlogiston, had disappeared. It was quite natural to assume this, because by observing the combustion of such substances as wood, coal, charcoal, etc., the disappearing of something was obvious. We now know that the disappearing substance changed into invisible gases, but in those days it

Digitized by Google

was natural to assume that combustion was not connected with the addition of something, but with the disappearance of something, and this something they called phlogiston. We must therefore look upon the phlogiston theory not as sheer nonsense, but as the result of an entirely logical generalization, combined only with one mistake, which was discovered later by actual measurements. But exact measurements are dependent upon the progress of science. Everything begins with rough observation; after the fact is known in a rough way closer investigation begins.

Now the oxygen theory as developed by Lavoisier accepted a very large part of the old phlogiston theory, namely, a general idea of combustion and reduction; it only explained that combustion means the union with oxygen; and reduction the separation from oxygen. Therefore the oxygen theory of combustion could not be established before oxygen was known. It was discovered by Scheele, and at the same time independently by Priestley.

The oxygen theory of combustion proved more satisfactory than the old phlogiston theory, because oxygen was a substance known, investigated and measured; in short, was recognized as a chemical element, a kind of matter, while phlogiston existed only in a theoretical way as a property like the Aristotelian elements. It was impossible to get phlogiston in a bottle and employ it for scientific investigation, while it was possible to do this with oxygen.

This great change was brought about, as I have mentioned already, by the discovery of another law, which was known in its rudiments long before, but which was expressed clearly by Lavoisier, that is, the law of the conservation of weight. This law means that if we take a certain amount of matter (we use this term still, because everyone thinks he knows what matter is) and enclose it in some way so that nothing can be lost, we do not know of any change which may occur in this mass of matter which would cause a change in its total weight. Even if there is a chemical change occurring, this matter will not alter its weight, although some substances may disappear during this process and others may be formed. It is not self evident to assume, for instance, that by changing solid sulphur and gaseous oxygen into gaseous sulphur dioxide no change in the total weight will occur. There was no necessary connection known between weight and chemical change; for just as the other properties of matter are changed by chemical combination, the weight also might change. Indeed,

Digitized by Google

there was every possibility that a change in weight might occur. It was so little impossible that a most distinguished chemist, Professor Landolt of Berlin, sacrificed fifteen years of his scientific life to investigate this very question, *i. e.*, whether there is any change of weight connected with chemical change, with the result that he could discover in most cases a slight diminution in weight. He is not quite sure if the diminution is really connected with the chemcal process, but he has observed it. This is just the point of this most difficult and refined investigation, to tell if the diminution is real and connected with every chemical change, or dependent upon some incidental circumstances. So you see that the conservation of weight is by no means a self-evident proposition. Self-evident things are things which we do not take care to investigate closely and it was simply a scientific question whether in chemical combinations there is a large change in weight, a small change, or no change at all.

Therefore it was an important discovery to show that in a great number of cases no appreciable change in weight occurs. And Lavoisier by using the balance secured a very simple means for defining an element. If we start with a certain amount of a certain substance, and bring about a chemical change of any kind, and then ascertain in what wise the weight has changed, we shall observe one of three possible cases: either the weight has diminished, the weight has increased, or the weight has remained unchanged. If the weight has diminished, the fact can be explained on the basis of the law of conservation of weight, only by the assumption that something has gone away, for example, a gas, and that therefore our substance was a compound one. To give an instance: If we heat mercury oxide, and change it into mercury, and find there is a certain loss of weight connected with this change, we must conclude that some substance has gone away from the mercury oxide, and therefore the mercury oxide is certainly a compound of mercury. Mercury itself may be an element, but this is not yet proven. We will first have to investigate all the possible changes of mercury, and if we find that all possible changes of the mercury are connected with an increase of weight, then we may define mercury as an element.

On the basis of the law of the conservation of weight, we can therefore define an element, and this has practically been done since Lavoisier. *An element is any substance which can be changed*

Digitized by Google

into another substance only by increasing in weight, inversely, a compound is every substance which can be changed into another substance with a decrease in weight, depending of course on the additional fact that some other substance has been formed at the same time. This is the definition of an element which you will find in those text-books which are more carefully written than the ordinary text-books are. In ordinary text-books I do not think you will find any experimental definition of an element, for the writers assume in a general way that everybody knows what an element is, or define it by the help of the hypothetical atoms.

Now, we will turn to the last stage in the development of the concept of an element. An element must be a chemical individual, as I have already explained to you, and we must therefore enter into a more exact and close definition of the chemical individual. I have already indicated certain differences in water. We call distilled water a chemical individual in its modern sense, but neither sea water or river water can be so called. What is the experimental difference between these bodies? A sample of clean sea water, for example, is just as homogeneous as a sample of distilled water. If you observe it through the very best microscope, if you filter it as many times as you like, if you do everything to trace out heterogeneity, even if you put a drop of sea water on a Zeiss's modern ultra high power microscope, which shows about a thousand times smaller particles than an ordinary good microscope, you will never find, or at least there never has been found as yet, any trace of a heterogeneous mixture. Therefore, if we describe or define chemical individuals as homogeneous bodies, we do not get a complete definition, because there are many substances which are homogeneous in the proper sense of the word, *i. e.*, which are of such character that no heterogeneous parts can be observed, and which are, nevertheless, not chemical individuals. We do not call sea water a chemical individual, we call it a *solution*. Therefore it is necessary to indicate the following cases:

First, we have *mixtures* in the coarse but true sense of the word. If you take a piece of stone, of granite, for example, you can define easily with the eye the components of its mixture, the mica, the quartz and the feldspar; and so you can discover with other mixtures the different components by the help of the microscope; but in sea water you can not discover these differences.

Mixtures are therefore substances which can be identified as

Digitized by Google

heterogeneous by physical means. Solutions are substances which are *homogeneous*. But now what is the difference between a solution and a chemical individual? What is the difference, for example, in the behavior of sea water and pure distilled water? There is only one empirical difference which can be discovered: For example, take some sea water, measure exactly the boiling point when the steam begins to come off and you will find the boiling point at a certain degree, for example, at 101 degrees, but during the escape of more and more steam the temperature will rise higher and higher until at last the highest point is reached, when solid salt will separate out of the fluid. In another way, if you cool a sample of sea water, it will not freeze at exactly zero, but a little below zero. Then as you freeze out more and more ice from it you will observe that the freezing point goes slowly down until it reaches the lowest limit, when solid salt separates out besides the ice. It is quite otherwise with pure water. Pure water will boil down to the last drop at the same constant temperature of 100 degrees and it will freeze into ice to the last drop again at the constant temperature of zero. This is the real difference between solutions and chemical individuals. To describe this difference in scientific terms I shall have to go back to a most important work, the work of Josiah Willard Gibbs, late professor of mathematical physics at Yale University, and I do not hesitate a moment to speak of him as by far the greatest scientist America has as yet produced. He has been very little known and it is not altogether our fault that this is so, because the works of Mr. Gibbs are written in a most condensed style and it takes an enormous amount of trouble and labor to get a real understanding of his long papers. Besides they were printed only in the Transactions of the Connecticut Academy, which has but a local circulation, so that even now the work of Gibbs is much more accessible in the German Translation, which was published about ten years ago, than in the original English. In a short time a new edition of Gibbs' work will be printed by Yale University and I hope the University will take care to issue the book at a price as low as possible, for this most important work should be in the hands of every chemist and physicist; indeed, of every scientist interested in the new developments of science. There are still scores of important discoveries in these works of Gibbs. It will take a long time to extricate them from the mathematics in which they are immersed, but the future de-

Digitized by Google

velopment of theoretical chemistry will be largely dependent upon the work of Gibbs and will be proportionate to the translation of Gibbs' mathematics into an intelligible language.

Now the concept which is of importance at this point is the concept of a phase. A phase is a most simple thing. Every part of a mechanical mixture, as described before, is called by Gibbs a phase. In granite, mica is one phase. All mica together means one phase, the mica phase. The quartz is another phase, and feldspar is a third phase, therefore granite is, according to Gibbs, a mixture of three different phases. If we have a vessel partly filled with water and partly with vapor, then we have two phases again, because fluid water has properties of its own and constitutes one phase, and the vapor having other properties constitutes a second phase.

These phases may be of the same composition in the chemical sense, or of different compositions. This makes no difference in the meaning of a phase. Phase means just the constituent of a mixture which has its own properties. Now only by means of forming new phases can substances be purified. Pure ice freezes out from salt water and pure vapor distils from it. The formation of a new phase therefore, is a means of purification on the one hand, and a means of identification of a pure substance on the other hand. We purify water, and indeed every other substance, by changing it into another phase; for example by changing liquid water into vapor. Then, at the same time it becomes apparent whether the water is an individual or a solution. If during the formation of the new phase the properties of the remainder change, then we have to do with a solution; if not, it is a pure substance or a chemical individual. When, therefore, we wish to know if a homogeneous thing is a solution, a substance or a chemical individual, we have only to change it into another phase; if in this changing into another phase the change is connected with no change in the remaining portion, then it is a chemical individual. Otherwise it is a solution. This is an exact and purely empirical definition of a solution, and of a pure substance, and explains how a solution can be turned into pure substances by changing temperature or pressure or both.

Now we get in this way a new definition of an element. We may find some chemical individual in the sense just defined, which means a homogeneous substance, which may be transformed

Digitized by Google

into another phase the remainder during the transformation retaining its properties unchanged. This behavior will generally remain the same, if we change slightly the circumstances, of temperature and pressure. But we can generally find other circumstances, and at last, and especially if we raise the temperature and lower the pressure, our body will no longer behave as a chemical individual, but will behave like a mixture or like a solution. For example, vapor of water will behave the same through a very long range of temperatures, for if condensed, it will be condensed at quite constant temperature, depending upon the pressure. But if we heat it higher, to more than 2,000 degrees, then at last some of the vapor of water will change into a solution, for it will yield hydrogen and oxygen by dissociation, while some will remain vapor of water. Water is dissociated at very high temperature, and we may describe this fact in a scientific way, by saying while vapor of water is a pure substance, or a chemical individual at lower temperatures, it becomes a solution of hydrogen, oxygen and vapor of water at high temperatures. Of course, the so called mixtures of gaseous matters we must call solutions, because they are homogeneous. And so chemical individuals will behave in almost every instance. We can find some range of temperature and pressure where most chemical individuals will change into mixtures or into solutions, but not every substance will do so. Some substances exist, oxygen for instance, which we can treat in any and every way; we can extend our range of temperature and range of pressure to the utmost limits of experimental possibility and yet the substance will not change into anything we can call a solution or a mixture. Such chemical individuals, which withstand as such, the utmost limits of possibilities of experimental science we call elements. Here is a new and independent definition of an element. An *element is a substance or chemical individual which never becomes a solution or a mixture*, and compounds are these chemical individuals which under certain circumstances become solutions or mixtures. Every mixture and every solution can be separated by mechanical means or by change of phase into components. Therefore from every substance changed into a solution or mixture under proper circumstances we can obtain its components and by treating these in a similar manner we can at last get to the elements.

So by this absolutely general consideration we find a most com-

Digitized by Google

plete definition of an element. You see this definition has nothing to do with atoms and such hypothetical features. The whole definition rests simply and solely upon experimental facts, and besides you will see at once that anything which is regarded at one time as an element may be recognized later as a compound if meanwhile we have widened the limits of experimental possibilities.

Through the whole history of chemistry this general fact is apparent; every enlargement of our experimental possibilities, for example, the invention of the electric pile, of the spectroscope, etc., results in the discovery of new elements, *i. e.*, in the breaking down of compounds which have been regarded hitherto as elements into new elements. Therefore, no actual boundary between elements and compounds exists. It depends entirely upon our means of investigation. Every temporary boundary between elements and compounds may be shifted, and is shifted, by every changed condition of our scientific means of observation. And, further, this definition has its purely and entirely experimental meaning and no other meaning than this. By a closer and closer investigation, the law of the conservation of the elements becomes more and more exact. You will generally fail to find any expression of this law of the conservation of the elements in the ordinary text-books. This comes again from the atoms, because atoms are usually introduced so early that the experimental law of the conservation of the elements appears as a tacit consequence of the atomic hypothesis and not as an experimental law of high importance.

That it is impossible to change lead into gold, depends, of course, not at all on the atomic hypothesis, but is only a purely experimental fact.

From all chemical investigations the law of the conservation of the elements became more and more distinct and all our present chemistry rests on the use of this law.

Only recently a discovery has been made which may change our chemical concepts, I expect, even more than the discovery of oxygen and the establishment of the oxidation theory has changed our chemical ideas. I allude to the fact of the possibility of a transmutation of one element into another which was discovered about two years ago by Sir William Ramsay. You know to what I refer. You know that with this most wonderful substance, radium, Ramsay has made the discovery that if he placed radium bromide, for example, in a tube and pumped out

Digitized by Google

every trace of air and every volatile substance, sealed it up, and investigated the contents of this vessel after some time, he found traces of helium, *i. e.*, of another element quite different from radium. Radium has a very large atomic weight, but helium has a very small one; hydrogen, only, having a smaller value.

Here we jump from one end of our history to the other, and the task the alchemists tried in vain to accomplish, the transmutation of one element into another, seems to have been accomplished by Sir William Ramsay. His experiments have been repeated and so far as I know, in every case his observations have been confirmed, that in an otherwise absolutely empty tube, where nothing except a compound of radium was present, it was possible to discover after a time a certain amount of helium which increased as time went on. The helium could be removed, but after the further lapse of time nearly the same amount of fresh helium was found. Therefore, we must conclude that the law of the conservation of the elements does not hold true, that there are some exceptions. I believe, of course, that the subject needs only closer investigation to bring the quantitative side under some new law. But you see just as the law of the conservation of weight during chemical change was subject to doubts, so in the same way the law of the conservation of elements is doubted; and we find ourselves face to face with an enormous new class of facts, and must find out what other laws or other generalizations will obtain with these new observations, *i. e.*, with these quite unexpected and most important facts. The general definition of an element will not, however, be affected; but we shall only come to the conclusion — just as it was the case when Davy, almost exactly one hundred years ago, discovered that alkalies (which were recognized as elements at that time because nobody could change them into mixtures or solutions) were not elements, that the concept of an element must be shifted by this new discovery, to fit the new observations. But this I would like to point out; it is quite a new set of facts that we have here, a set of facts comparable with, but perhaps more important than the change which the discovery of oxygen brought about. We have here an enormous amount of energy developed during this change which is quite incomparable with any other facts. The most con centrated form of energy we have hitherto known is probably a mixture of hydrogen and oxygen, but the quantity of heat developed by the transmutation of say a milligram of radium is about 5,000,-

Digitized by Google

000 times greater than the quantity of heat developed by the combustion of a milligram of detonating gas, and, therefore, we have here quite another order of energy-relations.

This will in some way alter the development of our concept of an element. You will see, more and more in our later discussions, how the development of a scientific concept is similar to the purification of a chemical substance. With every step forward in our knowledge we find some new means of getting our concept freed from contamination, from unnecessary relations, and by this slow process of purification we obtain at last the most simple, the most general, the most experimental definition of the concept for the direction and regulation of the science.

The question as to whether we will ever be able to get all known facts and all experiments into a well-regulated set of laws, is a question I do not dare to answer. We must confess we know of an overwhelming number of facts which we can not bring as yet into lawful connection with other facts, but our control of single facts by means of general laws grows more and more complete every day, and therefore we cannot be sure that there will remain forever some things impossible for us to explain. From our general experience, we may therefore assume that every fact which is observed, properly measured and identified, in a scientific way, will find at last its place also on the shelves of regulated science; but we must make a large allowance for the work of the future; we must never think that our present means of explanation and connection are exhaustive; we must ever remember that the science of chemistry is a very young lady indeed, not more than a hundred or a hundred and fifty years old, and this means not a very great age for general human possibilities.

Digitized by Google

SECOND LECTURE. COMBINING WEIGHTS AND ATOMS.

Ladies and Gentlemen:

In the last lecture I tried to show you how, by a method of slow purification, the most general concept of chemistry was developed, the concept of the chemical individual. In just the same way as we purified such a chemical individual, in the same way the concept itself has been purified by bringing it into different phases and under different conditions; thus we throw away all that was unnecessary and retain only the constant, invariable portion of the general law.

This general law means that there are chemical individuals in such a sense that each individual is endowed with a certain set of quite distinct properties, which prove to be the same in every case when we get this substance, quite independent of the way in which we get it; and these properties are invariable characteristics of each substance as exactly as we can determine with our present means of measurement and observation.

Now arises a new question: Are there more general laws connected with this concept of a chemical individual? You see there is something arbitrary in the conception of this subject We could investigate in the same way the properties of solutions. Every solution has distinct properties; and we can measure them with the same exactness as we measured the properties of the pure substances. But we would have to investigate the hundreds of thousands of solutions which could be made up from two or three substances, and this would take a hundred or a thousand times the labor, therefore it is quite a practical question to reduce our investigation to pure substances.

Every discovery of a general law is therefore a most practical affair. The law reduces our work of investigating, knowing and describing the facts of chemistry. Instead of an infinite series of possible solutions we have only to deal with a limited number of pure substances, and if we know *their* properties we can predict to some extent the properties of the solutions made from them.

Then, when we have found the general law of chemical individuals, or a law which proves to be so successful in reducing our scientific work, then of course we look for other laws of the same

Digitized by Google

reducing power. Indeed there are such laws, closely connected with the first and most general law, the laws which are obtained by the study of the pure substances. One of these laws, which is besides not only true for pure substances, or chemical individuals, but also for every other kind of substance, solutions and mixtures in the same way, *is the law of the conservation of weight.* Of every chemical process it is true that the sum of the weights of the substances before the process is equal to the sum of the weights of the substances after the process, for chemical change does not alter the weight. This is only a special example of a more general law, because we do not know of any other change, for example, electrification or heating, etc., which would change the weight of the substances involved. Therefore we can not call this law of the conservation of weight a particular chemical law, it being a general law for all physical happenings, including chemical ones.

But there are still other laws, laws which are directly connected with chemical individuals. One of these laws we could deduce at once by simple reasoning, and I will deduce it in this way, although this law was discovered in a purely experimental way. If we start from the general law that every chemical individual is endowed with certain quite distinct properties, then we can apply it at once to chemical change. When we start from a given quantity of any chemical individual and change it by combination or decomposition into another individual, the law of definite properties provides also for the production of another substance which is definite as to its weight. This means, that when a body turns by chemical change into another body, there must be a definite ratio between the weight of the primary substance and the weight of the product obtained from it. If you take a certain quantity of mercury oxide and change it by heat to mercury and oxygen gas, then, knowing that all properties have numerical distinction, we can conclude at once, that from a certain quantity of mercury oxide we get a certain quantity of mercury, and that the relation between these two quantities must be constant; there must be a constant ratio of weight. Otherwise our chemical individual would not fit the definition of a chemical individual, because this definition claims that *all* properties of chemical individuals are definite. Moreover the ratio between both weights must be independent of the way we get the second substance from the first. If only those substances are the same they are endowed with the

Digitized by Google

same properties. This is the well known law of the constant ratio in chemical change.

This law was not discovered in the way I have developed it just now. Indeed, the possibility of deducing this law from a general discussion of a chemical individual is rather a late idea. I think you will not find it at all in the common text-books. The discovery of this law was purely empirical. It was discovered and proved in the end of the eighteenth century by the French chemist, Proust. He showed by careful analyses of natural minerals that, quite independent of the place where the mineral is found, and even if the mineral is obtained in the artificial way, there is a constant ratio in the weight of the mineral and the products of its analysis. For instance, he investigated sulphide of copper, and found the ratio between the sulphur and copper in this mineral to be constant. The discovery of this law was only a kind of fixing process of existing ideas. The old technical chemists used to convert ores into metals and make products from raw materials. These people knew very well that by using a certain amount of primary substance they obtained a nearly proportionate amount of the conversion product. But as the amounts obtained were somewhat dependent upon their skill, they knew this law of proportionality only as an uncertain approximation.

Now Proust showed that indeed the ratio was quite distinct and as closely constant as the accuracy of his analyses would permit. Then he had to defend his law against the attacks of an adversary, whose name we will meet in a later stage of our history, against Berthollet, one of the most prominent chemists of his time. Berthollet was of the opinion that Proust was wrong, not so much for empirical as for theoretical reasons, and that although his ideas were correct indeed in the main, their application to this peculiar case was erroneous. Berthollet expressed his conviction that different chemical substances would combine in varying ratios, which were dependent upon pressure, temperature, concentration and other circumstances. You see at once the mistake Berthollet made. He mistook *solutions* and *mixtures*, as the case may be, for chemical individuals. Because he analyzed solutions or mixtures, his analyses resulted in showing varying ratios. If he had only confined his investigations to true chemical individuals, he would have discovered just the same truths that Proust discovered.

It was not very difficult for Proust to sustain his contention and

Digitized by Google

prove in a convincing way that his discovery was true indeed. Since his work the law is admitted as generally true, that if any chemical individual is converted into any other, the ratio between the weight of the former substance and the weight of the latter substance is constant, and is dependent only upon the nature of these substances. Neither temperature, nor the mode of procedure, nor anything else has any influence on the numerical value of this ratio.

Then another man entered the field, who has not yet received his full share of honor in the history of chemical thought. He was a German chemist not connected with a university. He was a practical chemist in the porcelain manufactury at the end of the eighteenth century; his name was Jeremias Benjamin Richter, and he devoted his whole life to quantitative investigations in chemistry. Richter started from a most simple and very well-known fact, which does not seem to contain anything more than just the simple fact. The power of his genius is shown by the fact that he began to wonder about a thing which everybody knew, and which everybody took for granted, as a simple and natural thing. If you put a piece of violet litmus paper into a liquid, and it turns red, then you call the liquid acid; or if it turns blue, you call the liquid alkaline; if it does not change at all, then you call the liquid *neutral.* If now, you take two salt solutions, for example a solution of common salt and a solution of saltpetre, to use the oldest examples of this kind, and test both solutions with a piece of litmus paper you will find that neither one solution or the other will change the color of litmus paper, both solutions are neutral. Now put both solutions together, and test again with litmus paper, and the result is the simplest you can imagine; the mixture of both solutions is also neutral to litmus paper. It looks so self-evident that no one can ask any more questions about it. But J. B. Richter asked a question, and a very important one, and at last by answering this question he discovered a most unexpected and important law.

We will assume the theory of the composition of neutral salts prevailing in his time. In his time the fact that by adding a basic substance, for example, potash or lime, to an acid, one could obtain a neutral salt, was a well known fundamental fact in every-day chemistry. Therefore he considered salts as formed by acids and by bases. Now we will investigate such a case as com-

Digitized by Google

mon salt, which is made up of the base, soda, and of the acid, hydrochloric acid, and saltpetre, made up of potash and nitric acid. If, now, we bring together both of these solutions, any one of several things may happen. Either the soda goes to the nitric acid, and the potash goes to the hydrochloric acid, both salts changing their constituents and forming corresponding new salts; or the two salts do not change their constituents, each salt remaining unchanged; or, finally, there may be a partial double decomposition of one salt into the other.

Now, it is known that by mixing the common salt with the solution of saltpetre, no changes in neutrality ensue, and salts of soda and chloride of potash, when mixed, remain neutral too.

In every case the mixture of neutral salts remains constantly neutral although in one of the cases, at least, there was a double decomposition. If you assume that common salt and saltpetre remain as such in the solution, then there would be complete decomposition if you mix nitrate of soda and chloride of potassium, because the two kinds of solutions if tested, in any way, prove to be absolutely identical, provided they contain the same quantities of their constituents. Therefore we come to the conclusion if in any case decomposition is either complete or partial, then in every case neutrality does not change. This reasoning sounds rather complex, because the two salts remain in the solution, but if you repeat the reasoning, for example with a solution of sulphate of potash and nitrate of lime, then a precipitate of sulphate of lime appears which is rather insoluble and double decomposition appears without doubt. But also in this case there is not the slightest change in neutrality.

Therefore we draw the general conclusion. If two neutral salts decompose each other by mutually exchanging acids and bases, they will remain neutral if neutral before; if this is granted, we can at once draw a most important quantitative conclusion.

We will keep our example. Take a solution of common salt and add to it saltpeter. We will assume that there will be a complete mutual decomposition. Now, we start from a known amount of common salt and add to it just enough nitrate of potash so that the soda of the first gets exactly saturated with the nitric acid of the second salt, then of course a certain amount of hydrochloric acid will be liberated from the first salt, and another amount of potash from the second. Now, this amount of hydrochloric acid

Digitized by Google

may combine with the potash, and the fact that neutrality remains shows that just as much hydrochloric acid was liberated as was necessary to saturate the potash, or, if you prefer, just as much potash has been liberated as is necessary to neutralize the hydrochloric acid, not the least trace less, or the least trace more. Therefore the permanence of neutrality during the double decomposition of neutral salts proves that their exist quite definite and general numerical ratios between the amounts of acids and bases forming neutral salts.

It is hard to realize the clearness of mind, necessary to see for the first time such a result from such a simple fact, and if I am not mistaken, you will find yourselves in some difficulty in following the idea. It is rather surprising to see that an important and quite definite law underlies this most commonplace fact: but it is indeed so.

The result of this reasoning, which may be extended of course to any number of salts, is nothing more or less than that there must be, first, not only quite a definite quantitative relation between the different acids and bases to neutralize one another, but that these relations are not independent one of another, but are interlaced in a certain way, because we can compare any pair of neutral salts either directly or by interposing other neutral salts. Take, for example, the following series of salts, indicated by the acids and bases from which they may be formed:

Hydrochloric acid,	Soda,
Nitric acid,	Potash,
Sulphuric acid,	Ammonia,
Acetic acid,	Lime.

We will assume that we start from a certain amount, say 1,000 parts by weight of the first salt, sodium chloride. Then we can take so much of the second salt that its nitric acid is sufficient to saturate the soda of the first salt, the fact that the neutrality is not changed proves that the hydrochloric acid, which has been set free by the decomposition of the first salt, is exactly sufficient to neutralize the potash set free by the decomposition of the second salt.

In the same way we can determine such an amount of ammonium sulphate, that its sulphuric acid will just neutralize the soda of the first salt. Then will the ammonia again be found to neutralize the corresponding amount of hydrochloric acid. But the same reason-

Digitized by Google

ing applies to the mutual decomposition between the second and third salt, and between the fourth salt and any one of the former salts. It is therefore possible to determine for every salt in this table, and of course for every neutral salt, a certain amount which will be "equivalent" in the sense just described to the 1,000 parts of sodium chloride we started with, and these amounts are not only equivalent to 1,000 parts of sodium chloride, *but all the amounts of the different salts as determined relatively to 1,000 parts of sodium chloride are also mutually equivalent to each other.*

You see this is a very important and most distinct law. It means that we can ascribe to every acid and to every base a certain number, and this number will express the quantitative relation between every acid and every base necessary to produce neutral salts.

By this reasoning of Richter's you recognize the existence of a numerical law, without making quantitative determinations, without knowing any of the numbers. You just go so far as to know there is such a law connecting the relative weights of the different acids and bases. There is a "combining weight" for each base and each acid, and these "combining weights" express the ratios between those acids and bases which result in forming neutral salts. This could be established without any measurement in the proper sense, just by testing with a piece of litmus paper.

You see the enormous power of reasoning, and see at once how important is this faculty of *being astonished by every-day things*, the faculty of wondering in the right place, which was the quality of Richter's mind and which guided him to this great discovery.

Richter's law was not accepted at once. We shall very often meet this same fact in the history of science; that the greatest discoveries find the greatest obstacles in the way of their being accepted by the leading scientists of the time. Richter published his work, but I must confess it was not in the simple form in which I have explained to you for the sake of brevity. He expressed his law in a more complicated form; I can not dwell upon it, but will say that while his expression means just the same, its form was more clumsy. Richter's books as published were rather difficult to read and understand, and chemists in general were not interested in them.

Then, in quite an accidental way, on translating an important work of Berthollet a certain Professor Fischer, of Breslau, men-

Digitized by Google

tioned Richter's work on neutral salts in a note, and at the same time he simplified the statement of Richter's law as we have stated it here to day. Then Berthollet introduced this note into his main work, his *Statique Chimique*, and pointed out that if Richter was correct it would change utterly our conception of salts, and, consequently he would like to see the matter investigated more closely, but he was not endowed at that time with sufficient scientific courage to undertake at once this most important investigation, *i. e.*, to find out if Richter's law was true or not. So this law remained almost unknown, and poor Richter even lost his fame when the importance of his discovery was recognized later by Berzelius, who found in Richter's law of combining weights an admirable test of the correctness of his analyses of neutral salts. For, if the combining weights of a number of acids and bases were known, all their ratios, and therefore the composition of neutral salts which may be made by these different bases and acids, could be computed at once. Now, Berzelius found that his analyses were mostly in accord with Richter's law and was ready to acknowledge its correctness. But as he was reading at the same time a similar work of another man called Wenzel, he mistook Wenzel for Richter and gave the whole glory of this great discovery to Wenzel, who was not connected with it at all. Thus the law was known as the law of Wenzel until the middle of the nineteenth century, when at last another chemist named Hess discovered that Wenzel, was really Richter, and pointed this out in a paper read before the Academy of St. Petersburg, which was printed in several periodicals. And so from that time the importance of Richter's discovery has been recognized and we find his name occasionally mentioned in the text-books. His claim indeed is very plain, because we have to acknowledge that Richter was the first discoverer of the existence of numerical laws for the relations of weights in chemical processes. Of course this law is only established for neutral salts. If a substance is not neutral, or not at all a salt, we cannot apply the reasoning of Richter, because the reasoning is based upon the fact that neutrality exists and remains in spite of double decomposition.

Now we come to quite another line of ideas, of the general law of combining weights of all substances, of elements and compounds. While Richter has discovered his law by experiment and proper reasoning, without the help of any hypothesis, the more general law had an entirely hypothetical beginning, for it was developed

Digitized by Google

on the basis of the atomic hypothesis, and it took a century to recognize that this foundation was not a necessary one, but only an accidental one. The leader was John Dalton.

Dalton started from the atomic hypothesis. We all know that the old Greek philosophers developed the hypothesis, that every substance, every mass of matter, was composed of very small particles, far too small to be observed by any physical means; thereby it was assumed that the possibility of dividing a mass of matter is limited, because at last we get to the atoms, and the atoms are called atoms because it was assumed they are not divisible any further. Now, Dalton was fully convinced of the existence of atoms, so much so that he never questioned it and never even started to investigate if atoms existed or not; he just assumed they must exist. By taking the atoms in earnest he came to an interesting consequence. If, for example, elements are composed of atoms, then the atoms of every element must be of a peculiar kind belonging to this element and to nothing else. They must differ in some way with different elements, in shape, in weight, in magnitude, and so on. Then, if a compound is made up simply by the combination of several different atoms, we must assume at once that the ratio of weight between the elements in any compound must be a certain invariable number, namely, the ratio between the weights of the atoms which make up these compounds from the elements.

To draw this conclusion only one question has to be answered beforehand, namely, are the atoms of a given element entirely equal among themselves or not? Is every atom of sulphur, for example, absolutely like every other atom of sulphur, or are there slight differences between the individual atoms, as dogs and horses are slightly different from each other?

Now Dalton went through just the same range of ideas that I developed to you in the last lecture. He reasoned that if he investigated pure sulphur, or pure water, and then changed it partially into some other substance and investigated the remaining part, and found the remaining part to have the same properties as the original quantity, *then all atoms of this substance must be alike.* If some of the atoms of sulphur or water were, for example, a little lighter than another, then the lighter part would go away first and the remaining part would contain the heavier atoms and would show other properties, and there would be some change in the proper-

Digitized by Google

ties by partial transformation. Just because the properties remain constant, as experience shows, on partially changing the substance into some other, we may draw the conclusion that the atoms of every chemical individual, if they exist, are exactly alike, one with the other, and that, therefore, atoms of a certain kind must have exactly equal weights. This weight may be very small, indeed, so small as not to be determinable at all, but it must be definite in value. If, now, different atoms are combined, there must be a certain ratio of the weights of these different atoms to form the compound.

You see the consequence of this hypothesis. It has just the power of extending the experimental law of Richter, by the hypothetical consideration, to all chemical individuals or compounds related to the elements; and of course we can invert the reasoning at once. If we start from compounds and make elements, then we must conclude that a certain amount of the compound goes to form the elements in a certain ratio, because the compound is composed of simple atoms with unchanging properties.

Dalton developed his idea rather slowly. He published it first in a paper on quite another matter. It was a paper on the Absorption of Gases by Liquids, and somewhat accidentally, he put a remark into the text that he had investigated the properties of the atoms more closely, and determined the ratios of their weights. Then he wrote a letter on the subject to a friend of his, Professor Thomson of Glasgow, who, was at that time an author of chemical text-books, and Thomson put Dalton's ideas into the Third Edition of his Text Book on Chemistry. In this way Dalton's ideas became somewhat better known. At last Dalton published a book of his own, in which he treated the consequences of his hypothesis as a fact indeed and deduced in an *a priori* way all the different peculiar laws which may be deduced from the general assumption; that a substance is composed of elements or atoms of a peculiar kind, a peculiar weight, and that therefore all combinations between elements must take place in the ratio of these atomic weights.

This is Dalton's share, and we see at once a large difference between Richter's work and Dalton's. Richter started from a purely experimental basis and drew his conclusions from it by simple and exact reasoning; while Dalton started from a hypothetical assumption, which could not be tested immediately, and drew from it consequences of the utmost importance, but whose truth re-

Digitized by Google

mained still to be proven. The hypothesis itself, of course, can never be considered as such a proof, but only as an indication that something like this hypothetical thing may be found in nature if it is properly investigated. Dalton was so convinced of the truth of his hypothetical assumptions that he considered it quite unnecessary to waste his time in proving it by experiment. He showed in a couple of cases that certain consequences of his hypothesis agreed with experience, and was quite satisfied in his own mind that things could not be otherwise than claimed by the hypothesis.

Then another man undertook the task of basing Dalton's law on experimental facts. This man was Berzelius. Berzelius published his work about 1809 in his native language, Swedish, but as in this language his discoveries would not reach the scientific world, his papers were published at the same time in the German language in Gilbert's "Annalen der Physik."

This work of Berzelius was executed in a most careful manner. He was busy developing analytical chemistry, which was hardly an art or a science at that time, in order to secure a reliable basis for general laws, and he sought some test for the correctness of his results. This he found in the law of Richter, and then in Dalton's hypothesis of the atomic weights, and he spent his whole life in working out the consequences, and in testing in an experimental way the theoretical consequences of Dalton's idea. The results were the best that anyone could expect. Berzelius found that Dalton's hypothesis fitted indeed exactly the facts, and that all his analytical determinations as to the ratio of the weights of the substance entering into or coming from chemical combination, could be expressed by the *law of atomic weights, or of combining weights.*

It is not necessary to explain to you this law again. Every one of you knows of course that we can ascribe to every element a certain numerical value, and that we do not know of any chemical individual whose composition may not be expressed by these combining weights or atomic weights, either by these values directly, or after multiplying one or both values by a simple integer taking for instance instead of one combining weight, 2, 3, 4, 5 or more. This certainly is a great discovery, which has proved itself to hold good throughout a century, and which forms the very basis of all numerical laws in chemistry. To these atomic or combining weights all other properties are to be referred in chemistry, and most of the physical properties of the elements and compounds

Digitized by Google

find a similar expression, if referred not to equal weights, but to chemically comparable quantities, or combining weights.

There are two quite different things in the idea of the combining or atomic weight; first, the numerical law, an empirical fact which holds, quite independently of the question whether atoms exist or not, for although we may deduce a law from the assumption of atoms, we cannot prove the existence of atoms in this way; the law rests upon analysis, upon quantitative investigation. On the other hand we can deduce the law from quantitative investigation, without any reference to the atomic hypothesis. We simply ascribe these empirical numerical values of combining weights to every element and then express the law by saying that elements only combine in ratios expressed by the ratios of their combining weights, either directly, or after multiplication by certain simple factors.

It is most important not to mistake the atomic hypothesis for the law of the combining weights.

Another question is, is it possible to deduce the law of combining weights from any other empirical facts? Are not these laws connected with some more general law? Is the assumption of atoms the only explanation of law? Generally it is assumed that the law of combining weights may be only deduced from the atomic hypothesis, but I would like to try to show you that there is another possibility. We can deduce the law of combining weights from another empirical fact in a way quite similar to that in which Richter found his law.

This empirical fact upon which to base the law of combining weights is the fact that compounds behave, by entering into more complicated combinations, just as elements behave. You will remember from the first lecture, that we know no essential difference between compounds and elements, for substances considered as elements might behave as compounds if we could only find a means for decomposing them. We may state this fact also by saying that compounds enter chemical combinations just as elements do, as integers. To show by an example, what is meant by this, I quote an experiment made by Berzelius. He started with sulphite of barium ($BaSO_3$) and changed it by oxidation into sulphate of barium ($BaSO_4$). Now, if there is a ratio between the barium and sulphur in the sulphite which is different from that in the sulphate a surplus of sulphuric acid, or a surplus of a barium salt, would be

Digitized by Google

formed. But when Berzelius investigated the liquid after oxidation, he found no trace either of sulphuric acid, or barium salt.

Therefore barium sulphite has entered the combination with oxygen so as to form barium sulphate *as a whole*, leaving behind no portion of its constituents.

Berzelius performed a number of similar experiments with other substances; for example, he changed lead sulphide, PbS, into lead sulphate, $PbSO_4$. The same result appeared in every case, that no surplus of one or the other element was found. Later Stas carried out similar investigations on a much larger scale, but with exactly the same result: in every case the compounds entered the new combination as a whole.

Now if we start from this general result we are led to a rather interesting consequence. Let us assume three chemical individuals, elements or compounds. For the sake of simplicity we will call them *A*, *B* and *C*. They may all combine in pairs and may all combine in only one ratio, and they can also combine to form the ternary compound *ABC*. More complicated cases could be treated in a similar way, but they would lead us too far. We start from a unit weight of *A* and combine it with *B* to form the compound *AB*. The weight of *B* necessary to form this compound we will call the combining weight of *B*, and the sum of weights of *A* and *B* the combining weight of *AB*. Now we combine this weight of *AB* with *C* to form the ternary compound *ABC*; the amount of *C* we call the combining weight of *C*.

Now we can proceed in another way to form the compound *ABC*. We first combine *A* with *C* to form *AC*, and then *AC* with *B* to form *ACB*. As the properties of a substance are independent of the way we get it, *ACB* is identical with *ABC*. But if this is so, then the ratio between it and *C* to form *AC* is no longer independent, for the combining weight of *C* in relation to it must be the same as it was in relation to the compound *AB*. Otherwise the ternary compounds *ABC* and *ACB* would not be the same. Therefore only one distinct combining weight can be ascribed to a chemical individual, independent of the elements or compounds which can combine with it.

Of course we can extend at once the same reasoning to any number of different chemical individuals and we find in this way the law of combining weights as a consequence of a purely experimental law.

Digitized by Google

This deduction is so simple that there is indeed some difficulty in understanding it, just because of its simplicity, but if you repeat this reasoning for yourself, you will find it is just as true as the reasoning of Richter was, and just as Richter showed the conservation of neutrality to be a sufficient experimental basis for his reasoning, in the same way we can deduce the law of combining weights from the fact that compounds behave just as elements behave, going into combination without leaving any remainder.

We can deduce, therefore, without the help of the atomic hypothesis the law of combining weights or of atomic weights, if you want to retain this name, showing that it is a consequence of a most general experimental fact.

Among the numerous laws and relations connected with the combining weights of the elements and their compounds I will dwell upon one only, which is most directly connected with these numbers. It arises from the question: Are there relations between the numerical values of the different combining or atomic weights?

I would like to point out that Richter even in his first work, in his examination of the combining weights of bases and acids tried to find out just the same relation which Newlands, Lothar Meyer and Mendelejeff discovered later for the combining weights of the elements. Richter asserted that when he arranged the combining weights in the order of their magnitude there were certain numerical relations between the numbers of the neutralizing quantities. Richter spoiled his work, however, by too much speculation in these lines, as his analyses were not so good as his reasoning was, and the application of his numerical laws to inexact experiments was the reason for the rejection of his whole work. Even the idea of predicting future discoveries of unknown acids and bases from empty places in his series is to be found with Richter.

After the establishment of the general law of combining weights similar attempts were made. The modern conception of this question was initiated by Newlands, who put simply all elements into a series according to the magnitude of their atomic weights and then discovered, that this series could be divided in a number of shorter series, each containing eight elements, in such a way that the corresponding numbers of these short series exhibited similar properties. When Newlands laid his first paper before the British Association, his way of looking upon the matter was so unexpected

Digitized by Google

and seemed so strange, that the president of the meeting asked him if he had not tried to find similar laws by arranging the elements in an alphabetical order. And so the matter was dropped amid general laughter.

But about ten years later from two independent sides the same discovery was made by Lothar Meyer and by Mendelejeff. Both of these investigators showed that indeed distinct regularities could be observed in a table of the elements arranged simply according to the numerical value of their combining weights, and especially Mendelejeff proved that almost all properties of the elements and their corresponding compounds could be arranged in a serial order according to their atomic weights. It was therefore possible to predict the properties of unknown elements and their compounds from the empty places in the table and from the properties of the neighbors of these future elements. The brilliant confirmation of these scientific predictions by later discoveries exhibited at once the usefulness of the "periodic law" and the general power of the true scientist to act as a prophet, whose predictions really come true.

Digitized by Google

OVER-WINDING IN HOISTING OPERATIONS.

By ROBERT PEELE.

In the operation of hoisting in mine shafts, when everything is working smoothly and the engineer is attending to his duty, steam will be shut off at the proper time, and the speedof the engine slackened during the last few revolutions of the drum as the cage is approaching the surface. But if, through some derangement of the machinery, or through mischance or carelessness, the engineer fails to check the speed of the engine in time, the cage is in danger of running up into the head-sheave.

A serious accident may result from this, if the drums are large and the hoisting speed great. Such velocities as 3,500 or 4,000 feet per minute are not uncommon with direct-acting engines, and maximum speeds in regular working of 5,000 feet per minute, or even more, are sometimes reached with the huge drums of 30 feet diameter and over used at some deep shafts.

If men are upon the cage and it has been hoisted too far with steam on, the engineer must resort to the brakes and apply them instantly, even at the risk of injury to the engine. When human life is not at stake, and the cage is merely carrying a load of mineral, it is sometimes better to let it go, risking the injury that cage, rope and head-frame might sustain, rather than hazard the wrecking of costly engines by too sudden application of a powerful steam brake. In any case it would be a rather heroic measure suddenly to brake a heavy engine running at full speed, even if the brakes were capable of stopping it within the half or two thirds of a revolution usually required to raise the cage from the shaft collar to the head-sheave.

But there is another consideration. With a large plant, even supposing that the engine has been stopped by the brakes at the last instant, after a fast trip, what is to check in time the momentum of the 8,000 or 10,000 pounds of runaway cage, car and contents, rising at a speed of 40 or 50 miles per hour? To prevent the cage from dashing into the head-sheave it must itself have some sort of brake, wholly independent of the engine.

An accident from over-winding occurred some years ago at the vertical Red Jacket shaft of the Calumet and Hecla copper mine.

Digitized by Google

The sinking cage (a combination of bucket and platform), on which were ten men, was run up into the head-sheave. On striking it the coupling pin between the rope socket and cage broke, and the cage with the men fell 3,150 feet to the bottom of the shaft. A modification of the Koepe system of hoisting is in use at this mine, and it is probable that, owing to an unsuspected slip of the rope on the driving sheaves, the indicator showed the cage to be some distance below the surface, whereas, in fact, it had already reached the landing place. No safety catches were in use, and they are generally considered unnecessary for the Koepe system of hoisting when the speed is moderate; but at this shaft the cages are run very rapidly, and the impetus alone of the blow against the head-sheave, aside from any pull of the rope, would probably be sufficient to break the coupling. At the time of the accident the hoisting rope made but one turn around the pair of driving sheaves, and the slip must have been caused by overweighting the rising cage to a point beyond the safe frictional adhesion between the rope and the sheaves. Since this accident the rope is made to pass three times around the driving sheaves, and any appreciable amount of slip is impossible. By such a change, however, it is evident that the Koepe system loses one of its most characteristic features, since over-winding accidents then become possible and some kind of safety appliance should be provided. This has been done in the large permanent hoisting plant since installed at this shaft.

A very serious over-winding accident once occurred at the Consolidated Virginia mine on the Comstock Lode. Of the fifteen men on the cage, ten or twelve were killed outright. In this case the cage did not fall down the shaft. The men were thrown from the sheaves to the floor of the shaft house, fifty feet below, some doubtless having been crushed against the sheaves and upper timbers of the head-frame.

Numerous devices have been introduced with the object of preventing the fatal consequences of over-winding, and every fresh accident stimulates inventors to new contrivances. These devices may be divided into three groups: (1) Those which depend upon the use of some kind of "detaching-hook," placed between the cage and the rope. (2) Arrangements for automatically shutting off steam and applying the brakes. (3) Arrangements for cushioning the cage as it rises into the head-frame.

Digitized by Google

Detaching Hooks. — A detaching hook is a link of peculiar design, forming the connection between the rope socket and the cage. When the cage has been over-wound and has reached a certain point in the upper part of the head-frame, the detaching hook comes into contact with a device which unlocks the connection and frees the rope from the cage. The rope passes away over the head-sheave, and at the same time by the operation of the detaching hook the cage is held suspended near the top of the head frame. Sometimes the detaching hook is intended only to release the rope to save it from being broken, the safety of the cage being left to the safety catches. But generally the cage is held fast by the same apparatus that releases the rope.

None of these devices really prevents over-winding; they merely do what is possible to avert or mitigate the serious consequences resulting from it. Some detaching hooks are found to work satisfactorily with moderate hoisting speeds, such as may be attained by geared engines — say up to 1,200 or 1,500 feet per minute — where the momentum of the cage is comparatively small. But no detaching apparatus can deal successfully with the high velocity reached by a heavy cage and load hoisted by a large direct-acting engine. The rope may be freed at the last moment, but a tremendous shock and some damage are inevitable. It is true that the cage is prevented from being pulled clear over the head-sheave — an accident which has actually occurred — and after the collision the wrecked cage may be supported by the detaching apparatus, but if men are on the cage they would have a poor chance for their lives.

The principle of the design and operation of the detaching hook may be set forth by describing several well known forms.

King's Detaching Hook. — In its usual form this hook (see Fig. 1) is composed of five steel plates of peculiar shape, placed together side by side and pivoted on a central pin or bolt, so that they will open when released, something like a pair of scissors. The two outside plates are fixed and are of the same pattern. The three inside movable plates are also alike, but the center one is set in the opposite direction to the other two. The center plate is not absolutely necessary; one of the others might be reversed in position in place of it. It is introduced to strengthen the hook and prevent torsional strains against the other plates, caused by the jerking and jarring of the cage while ordinarily running in the shaft. It is evi-

Digitized by Google

dent that even a slight distortion of the plates might cause them to stick and refuse to open at the proper time. The plates being pivoted on the center pin or bolt, when the rope is attached they are prevented from opening in regular hoisting by a copper rivet passing through all from one side to the other.

A strong timber frame is placed in the upper part of the head-frame, just below the sheaves, and in it is set a heavy cast-iron or steel plate, called the "disengaging plate." This is perforated by

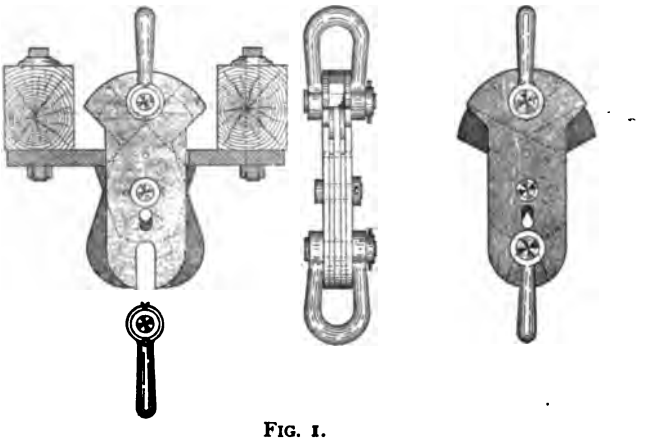


FIG. 1.

a large circular hole, one half inch greater in diameter than the width of the upper part of the detaching hook. The hoisting rope passes through this hole and thence over the sheave. In case of over-winding the lower projections of the movable inner plates of the hook strike the disengaging plate, and by it are pushed inwards, while their upper ends provided with catches are forced outward, revolving through a small arc in opposite directions upon the central pivot.

The copper rivet referred to above, which has no great strength is sheared off by the sliding of the plates on one another when the hook is called into play. By this movement of the plates the opposed slots in the upper ends of the inner plates are opened, and the clevis attached to the rope is forced into the straight upright slot of the outside plates, thus liberating the ropes. Simultaneously, the shoulders on the outer edges of the inside plates are thrown outward, and catch upon the edge of the horizontal disengaging plate, thus holding the cage suspended.

Digitized by Google

To lower the cage from the disengaging plate, after over-winding has occurred, an extra long clevis is inserted in the hole above the

FIG. 2.

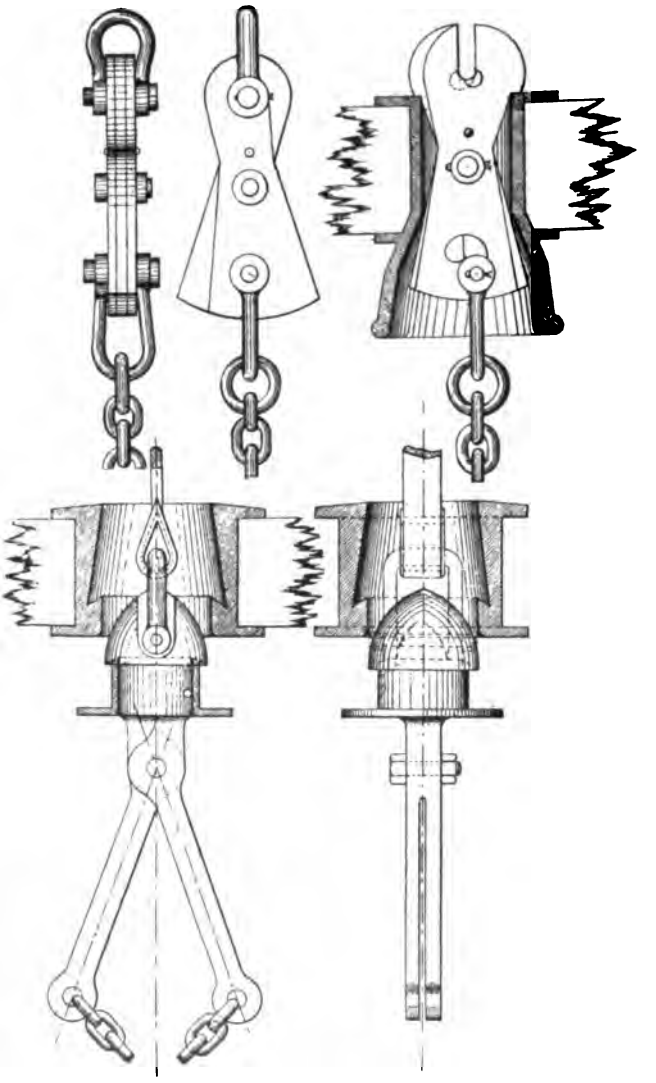


FIG. 6.

center pivot. Then the end of the hoisting rope is brought back, attached to the clevis, and by putting a slight strain on the rope,

Digitized by Google

the plates fall back into place, and the cage is lowered to the landing. The regular rope clevis is put into its proper place, a new copper rivet inserted, and the hook is again ready for duty.

For a hook 24″ long × 10″ wide, with a capacity of 6 tons, the clevis pins and bolts are each 2″ diameter. The outside fixed plates, for this size detaching hook, are ⅝″ thick, the two middle swinging plates ¾″, and the center plate 1″ thick. The disengaging plate, if of cast iron, is 30″ × 36″ × 1½″, with an opening 10½″ diameter. If made of steel it may be somewhat lighter, Four ton hooks are also made.

Ormerod Detaching Hook.— The Ormerod hook (Fig. 2) was formerly used to some extent. It is similar in principle to the King hook, but has only three plates. With this hook is used a heavy disengaging bushing, instead of a flat plate. It is bell-shaped, with the larger opening below. In regular work the plates are held together by a copper rivet, as with the King hook, and the rope is released in a way similar to that already described. The main difference in this design is that the instant the shoulders of the plates catch upon the upper edge of the bushing and the rope is set free, the lower clevis pin by which the cage is attached, is forced out of its seat into a connecting curved slot in the outside plates (see Fig. 2). By this means the plates are locked in position and the projecting shoulders are prevented from sliding by any possibility back off the rim of the bushing. The Ormerod link locks so firmly in the disengaging bushing that it is difficult to release it for lowering the cage. It is therefore necessary to raise the cage slightly by a temporary tackle, to unlock the clevis pin from the lower slot. At the same time, the end of the main rope is brought back and attached to a pair of eyes on the upper ends of the inside plates. Then by hoisting slightly, the plates fall into their original positions, and the cage is lowered to the ground.

Walker's Hook.—This consists of a pair of bent jaws, working on a central pivot (Figs. 3, 4 and 5). To the end of the hoisting rope is attached an eye-bolt with a head shaped to fit a pair of circular recesses in the upper ends of the jaws. The pull of the rope tends to force open the jaws. This is resisted by a heavy collar *H*, with an opening through which two rivets *I*, are inserted to keep the collar in place. When the hook enters the disengaging plate the collar strikes against the plate and is forced downwards, shearing off the rivets. The jaws are opened by the collar, as shown, the

Digitized by Google

rope is released. and at the same time the cage is supported by the projections on the outside of the jaws, which catch upon the edge of the disengaging plate. The collar is sometimes lined with a

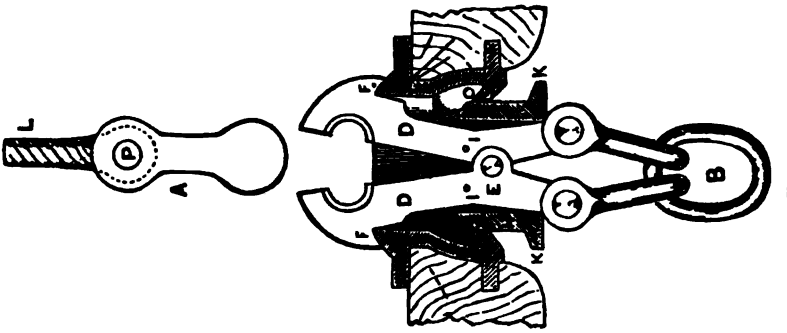


FIG. 5.

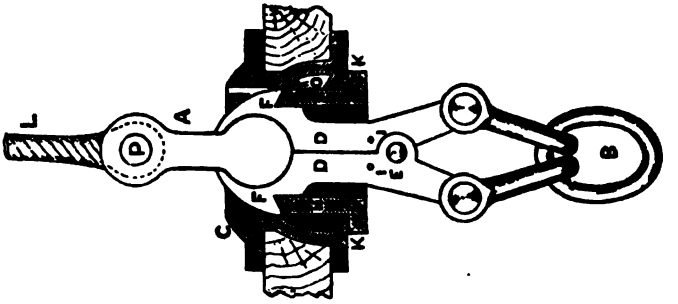


FIG. 4.

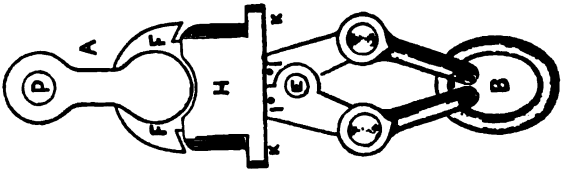


FIG. 3.

brass bushing, which does not rust, and facilitates the sliding of the collar. These hooks are made for 4 and 6 ton loads.

The three detaching hooks described above have been in common use for years in England and on the Continent of Europe, and rank with the best of their class. They are also used to a con-

Digitized by Google

siderable extent in this country. Several other styles of hook, as used on the Comstock lode and elsewhere, are shown in Figs. 6 and 7.

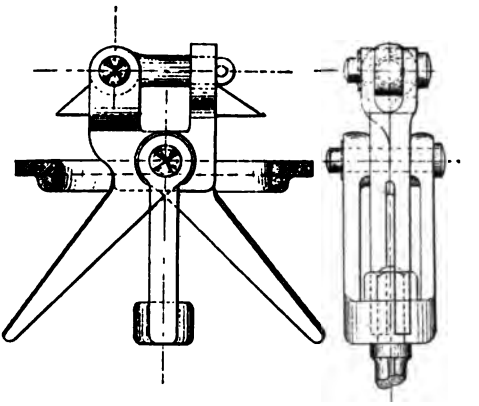


FIG. 7.

Mechanism to Shut Off Steam Automatically. — The second mode of preventing over-winding is to introduce some mechanism whereby steam is shut off from the engine, and the brakes applied automatically, whenever the cage passes a certain point above the landing chairs at the mouth of the shaft. There is no detachment of the rope; the engine is simply stopped. One device is as follows:

A heavy weight is suspended from a brake lever attached to regular engine brakes. Under ordinary circumstances, the weight is prevented from acting on the brake by a trigger arrangement which supports it. But when the cage is raised too high, it strikes a rod projecting over the shaft mouth, and in so doing trips the trigger, which allows the weight to fall, thus automatically putting on the brake. By the same movement also the throttle valve is closed. The weighted lever may be attached to the ordinary engine brakes, or to a special brake provided for the purpose.

This method is effective for slow speeds, and may be applied to the smaller geared engines, but, for the reasons already stated, such an apparatus is entirely useless for direct-acting engines working with high hoisting speeds. It might serve to prevent accident, however, in case the engine were started the wrong way when the cage is at the surface landing, and is about to be lowered. This not infrequently occurs, but the engineer would be likely to discover his mistake before much headway is attained.

Digitized by Google

Instead of waiting until the cage has actually reached the surface before the steam is shut off, a contrivance has been proposed by which steam is automatically but gradually throttled as the cage approaches the surface. The speed is thus reduced, and if, through inattention of the engineer or some derangement of the machinery, the cage rises too far above the surface, the brakes are also thrown on.

Such devices are all very well so far as they go, but until some one invents a method to save expense by doing away with engineers altogether, their introduction is hardly to be recommended. Automatic safeguards are themselves a source of some danger, on account of their tendency to make men careless and then failing to act when called upon at a critical time. An apparatus such as that last mentioned must act every time the cage ascends, and so long as it is in good order would really make it unnecessary for the engineer to attend to shutting off steam before the cage reaches the landing. But this would impart a feeling of security to the engineer, as though relieving him from part of his responsibility. Such a state of things would be all wrong, and surely prepare the way for an accident sooner or later. The hoisting engineer must be thoroughly alive to his responsibility every minute while on duty. In order that he may be wide awake and efficient, it may be added that his day's work should never exceed eight hours, at a shaft where men are raised and lowered; nor, in fact, at any shaft where the engines are kept constantly employed. Automatic appliances for shutting off steam should as a rule be done away with as accident breeders. It might be objected that, taking this view of the matter, detaching hooks themselves are inadvisable, but it is not so. A detaching hook is useful to a certain extent, but is naturally looked upon as a last resort. An engineer would consider himself much to blame if, through his fault, it were brought into action. For, unless the hoisting speed be moderate, he knows that some damage is likely to be done, even if the hook works properly, and furthermore, if the speed be great the hook will probably fail to save the cage.

Another point in connection with the detaching hook should be mentioned. When the rope is released suddenly under considerable speed and strain, the loose end is very likely to do mischief as it lashes over the head-sheave; and the engineer out of regard for his own safety would never desire to see the hook come into

Digitized by Google

action unless he had the side of a substantial engine house between himself and the head frame. Still another consideration, holding good for all mechanical appliances not in constant use, is that they are apt to become rusted and stiff, so that they may fail when called upon to do their work. Fortunately accidents of this kind are not of very frequent occurrence.

Among the numerous automatic contrivances for shutting off steam and applying brakes, there is really not one that is or can be perfectly satisfactory in dealing with high hoisting speeds. Incidentally it may be noted that, according to a recent decree of the Belgian government, whenever men are being hoisted in a shaft a capable assistant is required to be near the engineer, to replace him in case of sudden indisposition, and, like the engineer, he must devote his entire attention to the signals and working of the engine.

Best Means of Dealing with Over-winding. — There is a very simple method by which much may be done towards easing the shock of an over-wound cage as it rises into the head-frame, viz: by cushioning, or gradually destroying the momentum of the cage. This may be accomplished in two ways:

1. *Application to Wire-rope Guides.* — The guide ropes, above the surface landing, are encircled by long powerful spiral springs, which are compressed when the cage rises too far. The brakes would be applied to stop the engine, and the springs stop the cage. The surface chairs can be arranged to fall out automatically whenever the cage passes them, so that, even if the rope were to break, the cage could not fall down the shaft. But the cushioning of the cage ought to prevent the rope from breaking, if the engine be stopped.

2. *For Use With Wooden Guides.* — The head-frame is made extra stiff and strong, and the guides are brought gradually closer together, beginning at a point just above where the cage ordinarily comes to rest upon the surface chairs; that is, the horizontal distance between the guides is diminished towards the upper part of the head-frame. As a result, when the cage rises too far, the guides bind upon it tighter and tighter, and the cage is brought to rest by the frictional resistance without a dangerous shock. This plan is undoubtedly effectual, for the cage will wedge itself so tightly that, even if the rope should break, it cannot fall. It has been for some time used in France and Germany, and has been proposed in

Digitized by Google

this country. It cannot fail if the head-frame and guides are sufficiently strong and unyielding to exert an elastic compression upon the sides of the cage when the latter rises too far. There may be some difficulty afterwards in loosening and lowering the cage, but it can be done by attaching to the cage a temporary tackle, to prevent its falling, and then forcing the guides apart with jack screws; or, a section of the guides on each side of the cage may be cut out without doing much damage.

In conclusion, aside from the arrangements just described, the best means to prevent over-winding are: (1) To keep the hoisting engine and attachments in thorough order. (2) To employ competent, careful hoisting engineers. (3) To build the head-frame high enough to allow a fair amount of clearance from the surface landing to the sheaves.

CHEMICAL CONTROL OF CANE SUGAR FACTORIES.

By WILLIAM D. HORNE, Ph.D.

The following notes are intended to afford a uniform method of chemical control of cane sugar factories working under diverse conditions.

The methods described have been compiled from the official methods employed in Java and in the Hawaiian Islands as well as from the experience of the writer and his collaborators in this field.

Some of the methods in use still require elaboration and perfecting, and it is desired that any improvements in method that can be suggested, when working along these lines, shall be indicated to the central office.

For convenience in work the following notes have been grouped under the five general heads of Standardizing Apparatus, etc., Measurements, Sampling, Analyses and Calculations.

Standardizing Apparatus.

Balances and Weights. — See that the balance arms are of equal length by balancing weights against each other and then changing them to the opposite pans, where they should again balance each other. An analytical balance should be sensitive to one tenth of

Digitized by Google

a milligram. A sugar balance should be sensitive to five milligrams.

The weights must be standardized against properly certified standard weights and must be in correct relation to each other.

Brix Spindles are to be checked by means of a pycnometer, getting the specific gravity of sugar or molasses solutions at different densities.

$$\text{Sp. gr. at } t^\circ\text{C.} = \frac{\text{wt. of sugar sol. at } t^\circ \text{ C.}}{\text{wt. of water at } 17.5^\circ \text{ C.} \times \frac{\text{wt. 1 c.c. } H_2O \text{ @ } t^\circ \text{ C.}}{\text{wt. 1 c.c. } H_2O \text{ @ } 17.5^\circ \text{ C.}}}.$$

Sugar Flasks must all be standardized to be in accord with the polariscope used. This generally requires flasks holding 100 gm. of water at 17½° C. Standardize a 100 c.c. pippette to deliver this amount, and standardize all flasks by this.

To find the weight of water at t° C. which shall have the same volume (100 c.c.) as 100 gm. at 17½° C. multiply 100 gm. by

$$\frac{\text{density of water at } t^\circ \text{ C.}}{\text{density of water at } 17\tfrac{1}{2}^\circ \text{ C.}}$$

Polariscopes must be set to be correct at zero and the deviations from the correct readings at several points on the scale between zero and 100 noted and allowance made for any such error in each reading made. The scale is to be checked by standard quartz plates and by solutions of sugar of known purity.

Polarization Tubes should be tested as to length by means of standard metal tubes of 100 and 200 mm. length, respectively. Cover glasses should be tested to see that they are not optically active.

Quartz Plates for standardizing the polariscopes should be compared annually with standard plates.

Thermometers should be compared with a standard thermometer which has been officially corrected.

Water Meters should be standardized by weighng a quantity of water passed through.

Tank Contents can be most accurately determined by filling from a barrel placed on a platform scale, weighing all water admitted and making a correction for temperature.

Measurements.

Cane. — Weigh in cars or carts before bringing to the crusher. At the end of the day's run subtract cane weighed but not crushed

Digitized by Google

from total cane weighed plus whatever was carried forward from preceding day. At the end of the week's run grind everything that has been weighed. Weigh the trash in one carload of cane once a week to determine the per cent. of trash in cane; or, if practicable, collect all the trash from cars and weigh daily.

Juice. — Weigh, if possible, the mixed juice. Otherwise measure in tanks of known capacity. This capacity is to be proved by filling with barrels of water weighed at a known and constant temperature up to an overflow pipe two inches in diameter or until a float with index above points to a certain height. The overflow is better. Take the temperature and a sample of each tankful. Make allowance for air volume in juice and for any precipitate of lime or other solids.

Bagasse. — Once a week or once a month weigh all the bagasse yielded from a trial batch of about ten tons of cane.

Water of Maceration. — Measure in measuring tanks or through a water meter, applying such correction to the meter as a trial by weight might indicate, as well as a temperature correction. Or calculate from Brix of dilute juice and Brix of first mill juice to find water of dilution.

Press Cake. — Weigh a cake from each end and from the center of a filter press daily; or weigh the entire cake from several presses daily. Great care should be taken to select fairly representative cakes and pressfuls.

Condensing Water. — The amount passed through the condensers daily should be calculated from the work of the pumps, or meter or otherwise.

Molasses. — Weigh when shipping. Measure volume as it is obtained in the factory in tanks. Take density with hydrometer standardized against a pycnometer, making temperature correction both in measuring its volume and in taking its density.

Sugars. — Weigh in bags as packed, deducting tare weight of bags.

Sampling.

Cane. — Select two or more canes from each car. From the canes cut central pieces extending from the center of one joint to the center of the next, using equal numbers of canes cut respectively from the bottom, middle and top canes as they grew. These short sections, each containing one joint in its center, are to be split with a knife and either a half or a quarter of each used.

Digitized by Google

Juice. — A continuous sample should be taken if possible. Otherwise take an hourly sample of mixed juice, and where maceration water is added take in addition a sample of the juice coming from the crusher and first mill combined. Take each hour 2 oz. of juice, putting it into a 32-oz. bottle containing about 10 gm. of anhydrous lead subacetate* in powder form. Take another similar sample for Brix, preserving with 8 drops of formaldehyde.

Bagasse. — Put successive handfuls from different points across the face of the last roll into a weighed can with a tightly fitting cover. 500 or 1,000 grams should be taken thus, twice in twenty-four hours.

Press Cake. — From every press samples of the cake should be taken from the middle and both ends by means of a circular cutting die two inches in diameter. The disks of cake should be taken from the center and from points four to six inches from the corners.

Sugars. — Sample every two hours, several bags, keeping in closed box for testing twice daily. Also take a sample from five or more bags in each strike for polarization.

Molasses. — From each strike a sample should be taken when the strike is half purged. A run sample should be prepared from a mixture of proportional parts from all the strkes of that run.

Meladura. — Take a portion from each tank or hourly samples of 2 oz. and introduce into a 33-oz. bottle containing ten grams dry lead subacetate. Test every twelve hours.

Magmas. — Take a sample from each strike. If it is impossible to test all the magmas individually make twenty-four-hour composite samples of 100 gm. of magma from each pan, keeping different grades separate. Keep covered and mix well before analyzing.

Entrainment. — Take hourly samples of 500 c.c. each of condensation water from each pan and each multiple effect. At the end of six hours evaporate 2,000 gm. down to 100 gm. in a broad flat pan over a water bath and analyze. The condensing water before entering the condenser must also be examined similarly. This is an investigation only to be made when the alpha-napthol test has indicated the presence in the condensation waters of appreciable amounts of sugar.

* Made by the Baker and Adamson Chemical Co., Easton, Pa.

Digitized by Google

ANALYSES.

Cane. — Determine fiber only. Weigh about 1 kilogram of the sample pieces, crush in small mill to extract about 720 gm. of juice. Weigh the bagasse after chopping into small pieces and mixing thoroughly; weigh out 4 or 5 gm. and after comminuting finely extract by water under pressure, first cold then hot. This can be done very conveniently in the following manner: A burette tube is arranged to pass vertically through rubber stoppers closing the ends of a fifteen-inch glass cylinder about 2 inches in diameter, easily made by cutting the foot off of an ordinary cylinder such as is used in taking the density of solution. A quarter-inch brass tube also issues from the bottom stopper, passes outward and upward at an angle of 45 degrees for two or three inches, then straight up to the level of the top of the large cylinder, then across and down through the upper stopper two or three inches into the large cylinder. The large cylinder is filled with water to a level an inch above the bottom of this tube. A Bunsen burner or other flame is placed under this outer tube at the bottom of its upright portion and thus gradually heats the water in the outer tube. At the highest point of the heating tube is a ⊥ connection for withdrawing the air before operating. A thermometer passes through the upper stopper and its bulb is placed by the middle of the charge of bagasse to be extracted, which rests on a cotton or other suitable plug in the bottom of the burette. Another plug is placed above the charge and water is admitted from a reservoir above to the burette. It passes out below by means of a rubber tube, which is brought up in goose-neck fashion to a point above the level of the top of the charge, and thence passes down again to the bottom level, where it is closed by a compression cock.

To operate the apparatus allow water to flow slowly down the burette tube until the charge is covered and water overflows from the rubber tube. Regulate the flow by means of the compression cock so that about 100 c.c. will flow off in ten minutes. After working ten minutes place a small flame under the heating tube so that the temperature indicated by the thermometer will rise to 65° C. in ten minutes more and keep it so for twenty minutes. Then increase the heat so that the water in the heating tube will boil in ten minutes more and keep the extractor running until no more soluble matter is extracted. Turn the apparatus upside down; wash out the charge into a filter and dry the fiber to a constant weight in a water-jacketed air bath.

Digitized by Google

Juice.— Strain through a cone of fine brass or copper sieving and allow air bubbles to separate. Take the density with a Brix spindle including a thermometer made in the spindle and provided with a multiple temperature correction scale.* For the polarization add to an unmeasured quantity of the juice sufficient dry lead subacetate to clarify, avoiding an excess, mix, filter and polarize. The per cent. of sucrose can be obtained by reference to Schmitz's tables and dividing the result there found by 1.1. The purity may be found (1) by Horne's tables, given in Spencer's new edition of his "Handbook for Cane Sugar Manufacturers," p. 314; or (2) by multiplying the polarization by the factor corresponding to the Brix, which is obtained by dividing 26.048 by the product of the Brix by the corresponding specific gravity; or (3) by dividing the percentage of sugar found by the Brix and multiplying by 100.

Glucose is determined in a portion of the original samples. Weigh 20 gm., add lead subacetate to clarify, make up 100 c.c. and filter. To 50 c.c. of the filtrate (= 10 gm.) add 10 c.c. double normal potassium oxalate solution, make up to 100 c.c. and filter. Use this solution for volumetric titration of 10 c.c. of mixed Fehling solution and 40 c.c. of water, using potassium ferrocyanide and acetic acid for the end reaction.

Bagasse.— Put 50 gm. bagasse into a tared flask having a neck 1¼ inches in diameter with 450 gm. water (containing 5 c.c. of five per cent. sodium carbonate solution) and boil gently for 1 hour with reflux condenser. A glass tube about 30 inches long and ¼ inch in diameter extending vertically through the stopper of the flask answers the purpose. Make up to the original weight, shake frequently, cool and filter, clarify the filtrate with dry subacetate of lead, filter and polarize.

$$\frac{\text{Pol.} \times 260.48 \times (500 - \text{gm. fiber in 50 gm. bagasse})}{100 \times \text{Sp. Gr.} \times 500} = \text{per cent. sucrose in bagasse.}$$

Or $$\frac{\text{Pol.} \times .26048 \times (1{,}000 - 2\ \text{fiber})}{100 \times \text{Sp. Gr.}} = \text{per cent. sucrose in bagasse.}$$

To obtain the Brix extract a sample without adding sodium carbonate, cool, filter and obtain Brix with spindle or preferably with Westphal balance. To obtain the purity of the residual juice in

*Made by A. A. Weisse & Co., 684 Park Avenue, Brooklyn, N. Y.

Digitized by Google

bagasse divide the per cent. of sugar in the extract by its Brix and and multiply by 100. The per cent. sugar in the extract equals

$$\frac{\text{Pol.} \times 26.048}{100 \times \text{Sp. Gr.}'}$$

using the dry lead to clarify.

Fiber can be determined on three grams in the same manner as in cane.

Syrups. — The Brix is taken directly. Then weigh off 26.048 gms., make up 100 c.c., clarify with dry lead subacetate, filter and polarize. The purity is calculated by dividing 100 times the polarization by the Brix. Or the syrup can be diluted without weighing to about 15 or 16 Brix and tested by Casamajor's method.

Magmas. — For moisture, weigh 100 grammes and add 400 gm. of water. Take the Brix and multiply by 5. 100 — solids thus obtained = water. The results, while not strictly correct, are still perfectly comparable, and serve to control the work.

Molasses. — Weigh 300 gm. molasses, add 300 gm. water. Take Brix and multiply by 2. Make up 26 048 gms. to 100 c.c. using solution of subacetate of lead and alumina cream to clarify. Withdraw 50 c.c. of this solution, add to it acetic acid to produce a neutral or slightly acid reaction, make up to 55 c.c., polarize this and multiply by 2.2. For glucose take 19.2 c.c. of the original lead filtrate, containing 2½ gm. molasses, dilute, with addition of potassium oxalate, to 100 c.c. and filter. Take 40 c.c. of this (= 1 gm. molasses) dilute to 100 c.c. and titrate as above. For moisture weigh off 1 gm. of the original molasses into a three-inch flat-bottomed dish about ⅝ inch high containing a glass rod, dissolve in water and add about 30 gm. ignited quartz sand weighed exactly. Evaporate with frequent stirring on open water-bath until it appears to be dry, which should be in thirty minutes. Then dry to constant weight in a water-jacketed air-bath, which should not require over two hours.

For ash, weigh 2 gm. into a weighed platinum dish, add sixteen drops of strong sulphuric acid, ignite gently to a fluffy ash, cool, add two to four drops sulphuric acid, ignite and weigh. Multiply by $\frac{9}{10}$.

The remainder, after subtracting the sum of the water, sucrose, glucose and ash from 100 can be reported as organic non-sugar.

Sugars. — Determine moisture in 2 gm. portion drying first for

Digitized by Google

one half hour on open bath and then until constant in a water-jacketed air-bath. Sucrose is to be determined by the present official method of dissolving 26.048 gm. in water clarifying with solution of basic lead acetate and alumina cream, making up to 100 c.c. filtering and polarizing. Glucose is to be determined in the clarified portion used for polarizing. 19.2 c.c. of the filtrate, representing 5 gm. of the sugar, or some multiple of this quantity is used, the excess of lead, if any be present, is precipitated by potassium oxalate, the whole made up to 100 c.c., filtered, and the glucose determined volumetrically with Fehling solution. Determine ash as above, in molasses.

Press Cake. — Thoroughly mash and mix discs of cake, weigh off 25 gm., mix into a thin batter with water, add solution of lead subacetate to clarify, make up to 200 c.c., filter, polarize and multiply by 2. For moisture weigh 5 gm. in flat-bottomed dish, dry on an open water-bath and finish in a water-jacketed air-bath.

Condensation Water. — Weigh 2,000 gm. in a shallow, flat-bottomed evaporator, like a tin milk pan, evaporate down to 100 gm., clarify with dry lead subacetate and polarize.

$$\text{Per cent. sucrose} = \frac{\text{Pol.} \times 26.048}{100 \times \text{Sp. Gr.} \times 20}.$$

Sewer Water. — Collect hourly and preserve in a bottle containing formaldehyde. Twice a day polarize a sample, clarifying with dry lead subacetate.

$$\text{Per cent. sucrose} = \frac{\text{Pol.} \times 26.048}{100 \times \text{Sp. Gr.}}$$

Calculations.

Cubic feet of water × pounds per cubic foot at average temperature = pounds of water used.

Cubic feet of juice × pounds per cubic foot at average Brix corrected for temperature = pounds of juice, undiluted or diluted.

100 weight of juice ÷ weight of cane = juice per cent. cane.

$$\frac{100\,(\text{Brix undiluted juice} - \text{Brix diluted juice})}{\text{Brix undiluted juice.}} = \text{dilution water per cent. dilute juice.}$$

Dilute juice per cent. cane × per cent. dilution water in dilute juice = dilution water per cent. cane.

Digitized by Google

Dilute juice per cent. cane — dilution water per cent. cane = undiluted juice, per cent. cane, called "Extraction." Or

$$\frac{\text{Bx. dil. j.}}{\text{Bx. undil. j.}} \times \frac{\text{wt. dil. j.} \times 100}{\text{wt. cane}} = \text{undil. j. per cent. cane} = \text{"Extraction."}$$

When maceration is employed find the Brix of the mixed undiluted juice from the Brix of the juice from the crusher and first mill combined, by multiplying by the factor

$$\frac{\text{Brix of mixed juice}}{\text{Brix of 1st mill juice}}$$

obtained when not macerating.

Dilute j. per cent. cane × sucrose in dil. j. = sucrose in juice, per cent. cane.

100 — Extraction = bagasse, per cent. cane.

Sucrose in juice per cent. cane, plus sucrose in Bagasse per cent. cane = per cent. sucrose in cane.

100 wt. water used ÷ wt. cane = maceration per cent. cane.

Dilution per cent cane

$$= \frac{\left\{1 - \frac{\text{Bx. dil. juice}}{\text{Bx. undil. juice}}\right\} \times \text{wt. dilute juice} \times 100}{\text{weight cane}}.$$

Per cent. of water of maceration which goes into dilute juice

$$= \frac{\left\{1 - \frac{\text{Brix dil. juice}}{\text{Brix undil. juice}}\right\} \times \text{weight of dilute juice} \times 100}{\text{weight of water used}}.$$

100 — this per cent. = the per cent. of maceration water remaining in th Bagasse.

The effect of macerating may be studied by the following formulas when it is impossible to weigh or measure the maceration water put on the cane. Let "normal juice" be understood as the juice it occurs in the cane. "Undiluted juice" or "mixed juice" is that coming from the mills without admixture of water. "Dilute juice" is that containing water. "Residual juice," that remaining in the Bagasse. "Maceration water" is the entire amount put on; "dilution water" is that passing off with the juice; "absorbed water" is that remaining in the Bagasse.

Digitized by Google

"Bagasse" is the fibrous mass as it passes from the last mill containing such amounts of proximate constituents as the treatment may have left in it.

Given the weight of cane ground, a;
Weight of dilute juice, H;
Brix of undiluted juice, b; diluted juice, c;
Per cent. fiber in Bagasse without maceration, d;
Per cent. fiber in Bagasse with maceration, e;
Per cent. water in Bagasse without maceration, f;
Per cent. water in Bagasse with maceration, g;

$$\text{Dilution per cent. cane} = \frac{\left(1 - \frac{c}{b}\right) H \times 100}{a}.$$

This gives the pounds of maceration water going into the juice.

$$\text{Absorbed water in macerated Bagasse, per cent. cane} = g - f \times \frac{e}{d} \times \frac{\text{per cent. Bagasse on cane}}{100}.$$

This gives the pounds of maceration water remaining in the Bagasse. The sum of these two = water of maceration, per cent. cane.

The per cent. of Bagasse on cane may be found by subtracting from 100 the per cent. of undiluted juice, whether this be obtained directly or through calculation from the diluted juice.

Efficiency of Saturation. — Find the tons of fiber, juice and water entering and leaving a set of rolls. (Tons water by meter.) Get the juice remaining in Bagasse per cent. juice entering = a.

Get water remaining in Bagasse per cent. water entering = b. $100b \div a$ = efficiency of saturation; that is the degree to which water has become thoroughly mixed with juice in the cane.

Yield of Sucrose from magma or other sources, on dry basis.

$$\text{Yield} = \frac{100 \text{ purity massecuite} - \text{purity molasses}}{\text{purity sugar} - \text{purity molasses}}.$$

If the yield of moist sugar from moist massecuite, meladura or other source be required multiply this value by $\frac{\text{Brix massecuite}}{\text{Brix of sugar}}$.

Digitized by Google

Yield of sugars per cent. sucrose in juice

$$= \frac{100 \text{ wt. sugars}}{\text{wt. j.} \times \text{per cent. sucrose in juice}}.$$

Sucrose recovered per cent. sucrose in cane

$$= \frac{100(\text{wt. sug.} \times \text{pol.} + \text{wt. mol.} \times \text{pol.})}{\text{wt. cane} \times \text{pol.}}.$$

Also applicable to sucrose in all other products, as Bagasse, press cake, molasses, etc.

NORTH AMERICAN INDEX FOSSILS.

By AMADEUS W. GRABAU and HERVEY WOODBURN SHIMER.*

Introduction.

Fossils are the remains of animals or plants, or the direct record of their presence, preserved in the rocks of the earth's crust from the earliest to the present time. They are the only reliable means by which the age of any geologic formation can be determined, and, as such, are of the utmost importance to all geologists dealing with the non-igneous rocks. Not all fossils are equally good indices of the age of the formation in which they occur, for some are of very great vertical, and others of very limited horizontal distribution. It is evident that neither will serve as a good index type. The best index fossils are those which combine a wide horizontal with a limited vertical distribution, such as the graptolites or the ammonites.

In general it may be said that the more precise the required identification of a horizon the more limited must be the range of the fossil or fossils which are relied upon to indicate that age. Thus while trilobites as a class may be relied upon as indicators of Palæozoic age, being unknown above this, a certain group of trilobites alone will serve to indicate Cambric age, while a genus (*Olenellus*, or *Paradoxides*) serves to indicate the lower or middle Cambric respectively. Furthermore, a certain group of species of *Para-*

* This work will be issued in installments in successive numbers of the QUARTERLY.

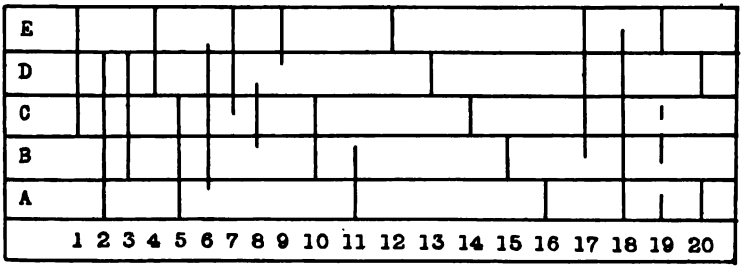
Copyrighted 1906 by A. W. Grabau and H. W. Shimer.

Digitized by Google

doxides, as for example the species of the *P. eteminicus* type, serve to indicate a certain horizon in the Middle Cambric.

It often happens that the fossils of a certain formation in a given region include no species of a restricted type, such as would indicate the exact equivalency of this formation with the ascertained horizon characterized by such a species in the type section. Under such circumstances it is necessary to determine the position of the formation in question by its assemblage of animal remains or *fauna* or the assemblage of plant remains or *flora*.

For example we may assume twenty species of organisms ranging through five formations, *A* to *E*, in the type section, as shown in the annexed diagram. It is evident that species 12 to 16 are the special indices of the formations *E* to *A*, respectively. We will now assume that a formation in another, not too far removed, region, contains none of these but has the following species generally abundantly represented: 2, 3, 6, 8, 17, 18, 19, while more rarely represented are: 1, 5 and 10. It is clear that this assemblage or fauna is most like that of formation *C* of the type section, even though species 14, the special index species of that formation, is wanting.



Influence of the Character of the Bottom and Sediment. — In the above illustration, the application is most reliable if the character of the sediment is similar to that of the type section, indicating similar conditions of existence. It is well known that with the change in sedimentation occurs a change in fauna, whole classes of organisms disappearing and new ones appearing. Thus nothing can be more distinct than the calcareous beds of the Beekmantown horizon of some parts of the Champlain Valley, with their trilobites, cephalopods and gastropods, and the black shales of the same age in the Hudson Valley, which contain only graptolites. It thus becomes necessary that the fossils of the formations of the type

Digitized by Google

section should be determined for the different phases of occurrence. This is necessary because each formation has normally an off-shore or pure water (generally calcareous) facies and a shore facies consisting commonly of quartz sands or even conglomerates, while between these two are various transition facies. * Furthermore a marine formation may in another region be largely represented by a continental formation, *i. e.*, a lake, river, or wind deposited formation. Examples of such more or less equivalent marine and non-marine formations are the Chemung and Catskill, the Pierre and Belly River, and the marine Tertiaries of the Atlantic and Gulf Coasts and the non-marine Tertiaries of the plains and Great Basin region. †

Types of Fossils. — Four types of fossils may be recognized, namely: (1) Actual remains and their impressions; (2) trails and tracks made by organisms in transit, and burrows; (3) artificial structures; (4) coprolites.

1. *Actual Remains.* — Generally only the hard parts of animals will be preserved but occasionally the fleshy parts also remain. Examples of this are the mammoths and other animals preserved in Siberian ice and the Tertiary insects of the amber found on the shores of the Baltic. The hard parts most readily preserved are the bones of vertebrates, the plates and spines of the external armor of fishes and reptiles, the exoskeleton of crustacea, the plated armor or test of echinoderms, the shells of mollusks and brachiopods, the "coral" structures of Bryozoa, corals, and hydrocorallines, and the shells of Protozoa. The horny covering of hydroids is also more resistant than other soft animal tissue and is commonly preserved in the form of carbonaceous films. Plant tissue is more readily preserved than animal tissue; especially is this true of wood, which is commonly preserved by being variously impregnated or replaced.

Molds and Casts.—Frequently the actual remains of the organism decays or is dissolved, leaving only a mold behind; when the structure was hollow, as in the case of shells, both external and internal molds (the latter often called casts) remain. Occasionally, by the infiltration of mineral matter into the mold, a *cast* of the ori-

* The principles here touched upon are fully treated in the forthcoming "Principles of Stratigraphy" by the senior author.

† See the table of formations in the appendix (published with the last installment).

Digitized by Google

ginal shell is produced. In the study of molds artificial casts must frequently be made.*

2. *Trails, Tracks and Burrows.* — Foot-prints of vertebrates on soft mud or sand and trails of worms, mollusks, or crustacea are often preserved. Here no part of the animal remains, nor is this the only impression made by the animal, as in case of the molds of a shell. Burrows of worms or other animals are more or less permanent homes, and are often reënforced by walls made of agglutinated sand particles. They then partake of the character of artificial structures, and they may be considered as intermediate between classes 2 and 3.

3. *Artificial Structures.* — Here belong the tubes built of agglutinated sand grains by worms, the "shells" built of similar foreign particles by many Foraminifera, and more especially the implements, habitations and other structures left by primitive man in the later rocks of the earth's crust, as well as the structures buried in historic times.

4. *Coprolites.* — The excrements of many animals are characteristic, serving to determine their presence in the formation in question. Typical examples of these are the coprolites of Jurassic and Cretacic reptiles.

Mode of Preservation.†

Under this heading we need to consider only the preservation of the actual remains (hard parts) of animals and plants.

Burial and Removal of Organic Matter. — The first step in fossilization is of course burial, for without that even the hard parts will soon be destroyed. This is well illustrated by the disappearance, largely through decay, of the bones of the American bison, which were left unburied in countless numbers on the western plains. It is also illustrated by the annual decay of the fallen leaves. After burial the organic tissue which forms the framework of all hard animal structures is removed by decay, thus rendering the remains more or less porous. This is well seen when a fresh bone is compared with one buried for some time. Tertiary shells often show the porosity due to the removal of the organic framework. This porosity is indicated by adhesion to the tongue, to the touch of which fresh shells feel perfectly smooth.

Infiltration. — Sooner or later the pores left by the removal of

* For processes of making these see appendix.

† For a full discussion of this see Grabau, A. W., "Principles of Stratigraphy."

Digitized by Google

the organic matter are infiltrated with lime, silica or other mineral matter, the organism thus becoming completely petrified or turned to stone. When silica infiltrates it tends to replace the original lime of the fossil, and in the end completely silicify it. Such silicification is commonly indicated by the formation of "Beekite rings," numerous small rings scattered over the surface of the shell or coral, and having at their centers a tubercle of silica. Silicified fossils commonly weather out in relief (though this is true also of calcified fossils), and they may be separated from calcareous rock matrix by acid. Silicification commonly destroys the minute structure of the organism while preserving its form. Many other minerals replace organisms, most common next to silica being iron pyrites. Wood may be partially or wholly silicified. In the first case the silica merely fills the cells and ducts, while in the second case the woody tissue is also replaced. Leaves may leave a picture of themselves in precipitated iron oxide, or they may be replaced by various minerals, or merely remain behind as a film of carbon.

Distortion often results from silicification, while crystallization frequently accompanies calcification, especially among the echinoderms.

Mechanical Deformation. — When rocks have suffered compression, fossils are commonly distorted. When the pressure is vertical the fossils are flattened out. This is frequently the case in undisturbed shales, where the compression of the beds, through pressure of overlying rocks, flattens out the shells, which in intercalated limestones or sandstones retain their normal form and rotundity. Where lateral compression has affected the strata various distortions result, which often may make the determination of the fossil a matter of difficulty. Brachiopod shells may in this way be made to resemble pelecypod shells.

The Naming of Fossils.

Each fossil is designated by a binomial term, the first part of which is the *generic* and the second the *specific* name. Generic names are written with an initial capital letter, specific names always begin with a small letter, even if derived from proper names. Thus *Heliophyllum halli* is correct, while *Heliophyllum Halli* is incorrect. The ending of the specific name (except nouns) must correspond to the gender of the generic name. The common endings

Digitized by Google

are *us*, *a*, *um*, or *is*, *is*, *e*, for masculine, feminine and neuter gender, respectively. Specific names derived from proper nouns remain the same for all genders and commonly terminate in *i*. The Greek ending *oides* remains the same in all genders. A generic name becomes a *synonym*w hen it is found that the same name has previously been used for an organism of another genus. It must then be replaced by another name. A specific name becomes a synonym when the genus in which it belongs already has a species of that name. Different genera may have species of the same name. Sometimes an author describes and figures under the same name several forms which are subsequently found to belong to distinct species or even genera. In all such cases new names must be used, the old names becoming synonyms for that species or genus, though holding good for the forms to which they were originally applied. In some cases a species or genus already named or a form belonging to a species or genus already established is given a new name by a later author. This new name then becomes a synonym and unless restored to rank subsequently *for the type for which it was proposed*, has no value whatever, but is dead. It can never be used again.

Table of the Animal Kingdom.

The following table of the animal kingdom takes account only of those classes which are represented among fossils, or, in other words, only such which have hard parts capable of preservation. The classes and subclasses in italics will be omitted in the succeeding discussions:

Phylum.	Branch.	Class.	Subclass.
IX. Vertebrata		*Mammalia.*	
		Aves (Birds).	
		Reptilia.	
		Amphibia.	
		Pisces (Fishes).	
VIII. Echinodermata	Pelmatozoa. Echinozoa.	*Holothuroidea* (Holothurians.)	
		Echinoidea (Sea Urchins).	
	Pelmatozoa. Asterozoa.	*Asteroidea* (Starfish).	
		Ophiuroidea (Brittle stars).	
		Crinoidea.	
		Blastoidea.	
		Cystoidea.	

Digitized by Google

Phylum.	Branch.	Class.	Subclass.
VII. Arthropoda		Insecta.	
		Myriopoda.	
		Acerata	*Arachnida* (Spiders).
			Merostomata (Eurypterids, etc.).
		Crustacea.....	Malacostraca (Lobsters, Crabs).
			Cirripedia (Barnacles).
			Ostracoda.
			Phyllopoda.
			Trilobita.
VI. Annulosa.....		Annelida.	
V. Mollusca.....		Cephalopoda.	
		Pteropoda.	
		Conularida.	
		Gastropoda.	
		Amphineura.	
		Scaphopoda.	
		Pelecypoda (Lamellibranchiata).	
IV. Molluscoidea*..		Brachiopoda.	
		Bryozoa.	
III. Cœlenterata		Anthozoa (Corals).	
		Hydrozoa (Hydroids and Hydrocorallines).	
II. Porifera.....		(Sponges.)	
I. Protozoa		Rhizopoda.....	Radiolaria.
			Foraminifera.

General reference works:

MILLER, S. A. North American Geology and Palæontology 1889 and appendices (lists all Palæozoic species with reference to literature).

BOYLE, C. B. Catalogue and bibliography of North American Mesozoic Invertebrates, 1893 (with reference to literature), Bull. U. S. Geol. Surv., 102.

WELLER, STUART. Bibliographic index of North American Carboniferous invertebrates, 1898 (with synonymy and reference to literature), Bull. U. S. Geol. Surv., 153.

PHYLUM I. PROTOZOA.

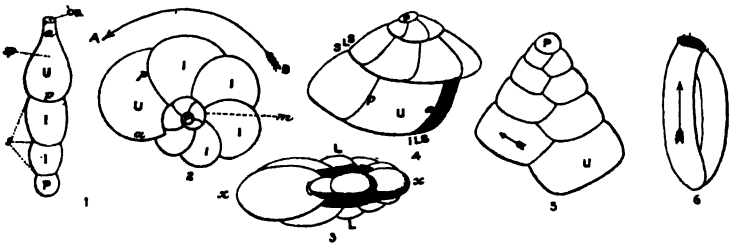
These are the simplest types of animals, with a body consisting of a single cell. Only two subclasses build hard structures which may be preserved as fossils. These are the Foraminifera and the Radiolaria. The first build external shells of lime, chitin or agglutinated sand particles; the second secrete more or less internal skeletal elements of silica and generally of an open lattice-like structure.

*Placed here for convenience so as to bring the Bryozoa and Corals together, many fossil forms of which are superficially alike.

Digitized by Google

Subclass 1. **Foraminifera** d'Orbigny.

The shell may consist of a single chamber (unilocular) or of many chambers (multilocular). The chambers may be arranged in a straight line (nodosarian type, Fig. 1), wound in a horizontal manner (nautiloid type, Figs. 2, 3), in a spiral manner (trochoid



FIGS. 1–6. Diagrams illustrating types of Foraminiferal Shell (after Bagg).

type, Fig. 4), alternating in a double series (textularian type, Fig. 5), regularly embracing the preceding chamber (milioloid, Fig. 6), irregularly clustered (globigerinoid, Fig. 14), simple globular (orbulinoid, Fig. 13), or wrapped about an imaginary axis — either disk-like (orbitoid, Fig. 19) or spindle-shaped (fusoid, Fig. 18). The shell is either pierced by numerous pores or foramina (perforate) or is imperforate. A terminal or oral opening is generally present. The shell is a secretion of lime or results from cementation of sand grains (Fig. 11).

Owing to the fact that the Foraminifera vary but slightly from the upper Paleozoic to the present, they are of very little use as index fossils. A few of the more abundant genera are here given in order that they may be recognized as such. A few species which are restricted in their geological range and are found in great abundance are described.

LITERATURE.

1876. **Brady, W. B.** Monograph of Carboniferous and Permian Foraminifera, Palæontographical Society Monographs.

1884. **Brady, W. B.** Report on Foraminifera, Scientific Results, Challenger Expedition. Zoölogy, XI.

1893. **Woodward, A.**, and **Thomas, B.** Cret. Foraminifera, Minn., Neb. and Ill. Minn. Geol. Surv., III., 28.

1898. **Bagg, R. M.** Cret. Foraminifera, N. J. Bull. U. S. G. S., no. 88.

Digitized by Google

1900. **Chapman, F.** Foraminifera from the Tertiary of California. Proc. Cal. Acad. Sci., Ser. 3, Vol. I., pp. 241–260, pls. XIX., XX.
1901. **Bagg, R. M.** Eocene Foraminifera. Md. Geol. Surv. Rept.
1904. **Bagg, R. M.** Miocene Foraminifera. Md. Geol. Surv. Rept.
1905. **Bagg, R. M.** Miocene Foraminifera of California. Bull. U. S. G. S., no. 268.

Synopsis of Important Genera and Species.

I. Peneroplis Montford.

Fig. 7. *Peneroplis planatus*, greatly enlarged.

Shell a flattened cornucopia, with the small end spirally enrolled and chambers extending the entire width of the shell. Tertiary–Recent.

1. **P. planatus** Montf. (Fig. 7.) Recent.

II. Cristellaria Lam.

Shell regularly spiral with coils completely enveloping one another. Oral opening round. Trias–Recent.

2. **C. cultrata** Montf. (Fig. 8.) Cret.–Recent. 3. **C. cretacea** Bagg. (Fig. 9.) Cretacic.

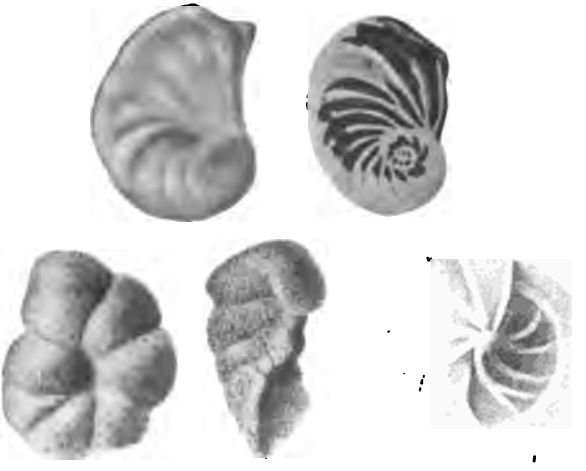


Fig. 9*a–b*, *Crystellaria cretacea*; 15, *Anomalina ammonoides*; 11, *Verneuilina triquetra*; 8, *Crystellaria cultrata* (all after Bagg), greatly enlarged.

III. Textularia Defrance.

Chambers in two rows, alternating with each other and gradually

Digitized by Google

increasing in size. Aperture usually an arched slit at the base of the inner wall of the last chamber. Carbonic–Recent.

4. **T. globulosa** Ehr. (Fig. 10.) Cret.–Recent. 5. **T. (Verneuilina) triquetra** (Münst.). (Fig. 11.) Cret.–Recent.

FIG. 10. *Textularia globulosa* (Minn. Geol. Surv.), much enlarged.

NODOSARIA.

Chambers in a single row, smooth or ornamented. Siluric (?)–Recent.

6. **N. communis** (d'Orb.). (Fig. 12*a*.) Perm.–Recent. 7. **N. bacillum** Defrance. (Fig. 12*b*.) Eocenic. 8. **N. zippei,** Reuss (Fig. 12*c*.) Cretacic.

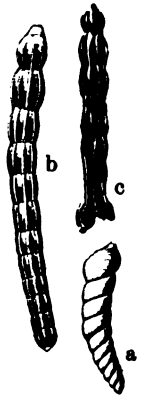


FIG. 12. *a*, *Nodosaria communis*; *b*, *N. bacillum*; *c*, *N. zippei* (*a–b*, Md. Geol. Surv.; *c*, Bagg), greatly enlarged.

V. ORBULINA d'Orbigny.

Shell a simple sphere with a large oral opening and numerous foramina. (Cambric?) Trias–Recent.

9. **O. universa** d'Orb. (Fig. 13.) Trias–Recent.

FIG. 13. *Orbulina universa*.

FIG. 14. *Globigerina bulloides* (Minn. Geol. Surv.), much enlarged.

FIG. 16. *Truncatulina lobatula* (Md. Geol. Surv.), enlarged.

VI. GLOBIGERINA d'Orbigny.

Free, calcareous, perforated by coarse tubules. Composed of several globular chambers, which are irregularly arranged or in an imperfect spiral. (Cambric?) Triassic–Recent.

10. **G. bulloides** d'Orb. (Fig. 14.) Cret.–Recent.

Globigerina, *Textularia*, etc., are very abundant in the American chalk (Niobrara) and also in the Atlantic and Gulf Tertiary.

FIG. 17. *Endothyra baileyi* (after Whitfield), much enlarged.

Digitized by Google

VII. ANOMALINA d'Orbigny.

VIII. TRUNCATULINA d'Orbigny.

Nautiliform or trochiform shells, the first nearly uniformly coiled, the second flat on one side, while on the other side the last volution covers most of the preceding ones. Carbonic–Recent.

11. **A. ammonoides** (Reuss). (Fig. 15.) Cret.–Recent; 12. **T. lobatula** (Walk. & Jacob) (Fig. 16) Carb.–Recent.

IX. ENDOTHYRA Phillips.

Free, calcareous, irregularly spiral. Chambers numerous. General aperture porous.

Abundant in Carbonic and continuing doubtfully to Recent.

13. **E. baileyi** Hall. (Fig. 17.) Lower Carbonic.

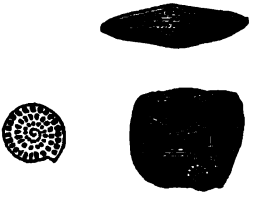


FIG. 18. *Fusulina secalina* (Ind. Geol. Surv.), natural size and enlarged.

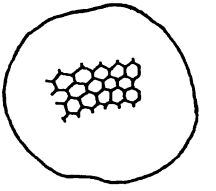


FIG. 19. *Orbitoides mantelli*. Outline and enlargement of peripheral portion.

Shell compressed, usually consisting of two or three oblique convolutions of which little more than the last is visible on the exterior. Margin thick, rounded, lobulate. Chambers inflated, separated by depressed septal lines, variable in number from seven to ten in each whorl. Diameter $\frac{1}{45}$ to $\frac{1}{20}$ inch or more.

Very abundant in Mississippian of southern Indiana.

X. SACCAMMINA Sars.

Free, consisting of a single subglobular chamber with central aperture or of a number of spindle-like segments joined end to end. Tubular prolongations at one or both ends of the chambers. Texture arenaceous, compact; smooth externally or nearly so and rough on interior surface. Ordovicic–Recent.

14. **S. eriana** Dawson. Devonic.

Shell globular, about 1 mm. in diameter with one aperture. Wall composed of minute calcareous grains, smooth interiorly. Outside smooth or banded by flutings.

Onondaga limestone of Kelley's Island, Ohio.

Digitized by Google

XI. Fusulina Fischer.

Fusiform, laterally elongated and furrowed, coarsely perforate. Chambers subdivided by numerous septa.

Exceedingly abundant in the Carbonic of North America, Europe and Asia. Carbonic–Permic.

15. **F. secalica** (Say). (*F. cylindrica* Fischer.) (Fig. 18.) Carbonic.

Spindle-shaped, with rounded extremities, which generally have the appearance of being slightly twisted. Volutions six to eight and closely coiled. Sometimes one half inch long.

Widely distributed throughout the Middle and Upper Carbonic.

XII. Orbitoides d'Orbigny.

Discoidal. Exterior smooth or ornamented with radial striæ. Composed of numerous concentric rings, which are divided by transverse partitions into small rectangular chambers. A median series of main chambers occurs. Upper Cretacic and Tertiary.

16. **O. mantelli** (Morton). (Fig. 19.) Oligocenic.

Discoidal, flattened, thin, thickest at center and tapering from there to the sharp margin. Diameter ½ inch to 1½ inches.

Very abundant in the lower Oligocene (Vicksburg) beds throughout the Gulf states, often forming beds of limestone.

Subclass 2. **Radiolaria** Müller.

The siliceous skeletons of these Protozoa are usually too much broken for identification. In exceptional cases, as in the Miocene of the Barbadoes, they are exceedingly numerous and well preserved. (Fig. 20.)

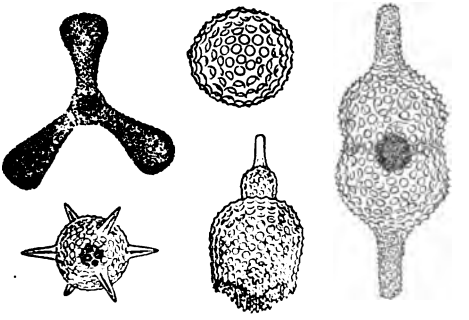


Fig. 20. Radiolaria. *a–b* (upper left), *Rhopalodictyum marylandicum; Cœnosphæra porosissima; c, Hexalonche microsphæra; d, Anthocyrtium doronicum; e, Cannartiscus amphicylindricus.* All Miocenic (Maryland Geol. Surv.), much enlarged.

Digitized by Google

PHYLUM II. PORIFERA (SPONGES).

Multicellular animals, chiefly marine; body penetrated by a complex series of canals, into which the water enters by the pores of the wall. These canals widen out into, or give off at intervals digestive chambers, and finally converge into one or more large canals which open on the upper side of the sponge in large craters or oscula. (Fig. 21.) Most modern sponges secrete a skeleton of horny fibers, which is frequently reënforced by silicious spicules of various forms. In many extinct types these spicules were the most prominent structure, and frequently became thickened and united to form a solid trellis or framework which retained the form of the sponge on fossilization. In some sponges this framework is regularly reticulated, in others it consists of very irregular branching spicules, while in still others it is apparently a solid mass of spicules. Some forms (*Dictyospongia*, etc.) were apparently delicate nets of siliceous fibers, the form and impression of these being preserved by the infiltrated sand as an internal mold.

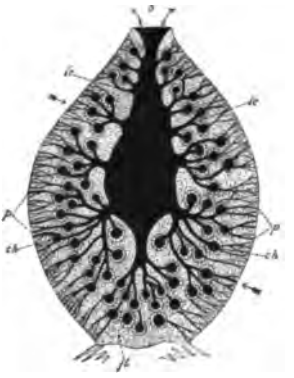


FIG. 21. Diagrammatic figure showing the structure of a simple sponge in vertical section. The sponge substance (*fl*) is lightly shaded. The canal system is black, the arrows showing the direction of the currents. *fp*, are the pores or openings of the inhalant canals (epirrhysa) which lead to the flagellate chambers, *ch*. From the latter depart the exhalant canals (aporrhysa), *ic*, which open into the general cavity or paragaster. *o*, is the osculum or aperture through which the water is discharged. (Haeckel, in Hall and Clarke.)

Sponges as a rule are poorly preserved and difficult of determination. They have been but little studied in this country.

LITERATURE.

1860. **Roemer Ferd.** Silurische Fauna des Westlichen Tennessee.

1889. **Beecher, C. E.** Brachiospongidæ, Mem. Peabody Mus. Yale Univ., II, pt. I.

1898. **Hall, J., and Clarke, J. M.** Palæozoic reticulate sponges. Mem. II. N. Y. State Museum. Also papers by Whitfield Hall and others.

Digitized by Google

SYNOPSIS OF IMPORTANT GENERA AND SPECIES.

I. Astylospongia Roemer.

Free, spherical, with a shallow depression on top. Base evenly rounded. Surface furrowed by large canals and pitted with pores,

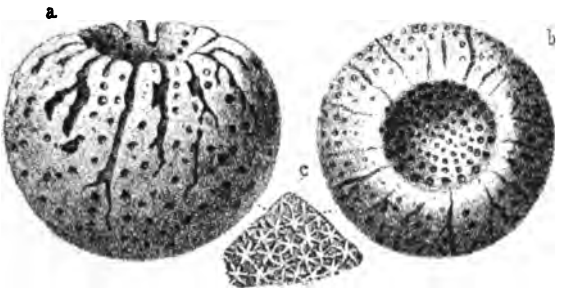


Fig. 22. *Astylospongia præmorsa*, with enlarged section (Roemer).

which terminate many fine radial canals. Spicules four-rayed and branching, with their nodes enlarged into knots. Siluric.

1. **A. præmorsa** Goldfuss (Fig. 22). Siluric.

Summit shallow and pierced with many large holes. From the edge of this depression radiate shallow furrows irregularly over the sides.

Niagara of Indiana, Tennessee, etc.

2. **A. inciso-lobata** Roemer. Siluric.

Differs from *A. præmorsa* in the absence of large pores above and in that the furrows number but six to eight and are deeply incised, thus dividing the surface into large, rounded lobes.

Niagara of Tennessee.

II. Hindia Duncan.

Free, spheroidal. Spicules form a series of bifurcating, straight canals radiating from the center and opening at the surface. Siluric.

3. **H. fibrosa** Goldfuss. Siluric.

Ball-shaped, about one inch in diameter. Surface covered with very small, irregular, polygonal openings.

Upper Siluric of Tennessee.

III. Dictyospongia Hall and Clarke.

Subcylindrical, very gradually expanding. Smooth, with no ornamentation except the reticulated meshwork of spicular threads.

Digitized by Google

Prism faces sometimes very obscurely developed toward the summit. Occurs as internal molds.

Characteristic of the Chemung and occurs also in the upper Portage and Keokuk.

4. **D. sceptrum** Hall. (Fig. 23.) Upper Devonic.

Elongate, usually abnormally compressed. Surface covered with coarse, transverse spicular bands from 10 mm. to 15 mm.

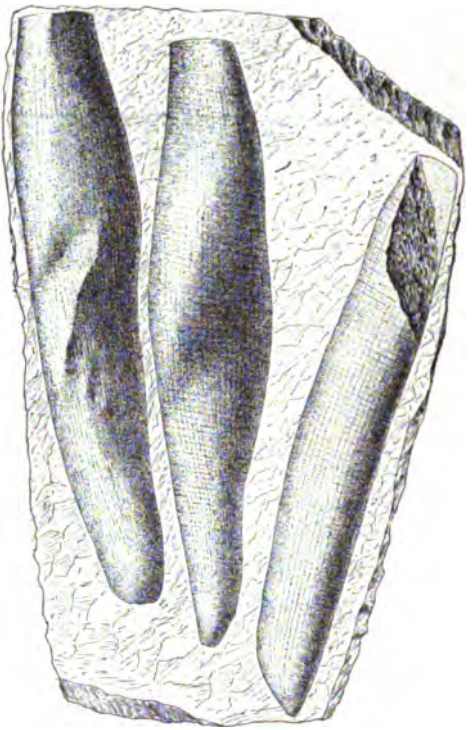


FIG. 23. *Dictyospongia sceptrum* × ½ (Hall & Clarke, N. Y. State Mus.).

apart and crossed by less conspicuous vertical bands about 5 mm. apart.

In the shaly sandstones of the upper part of the Chemung group in New York.

IV. PRISMODICTYA Hall & Clarke.

Elongate, usually slender, gradually expanding from the acute base. Surface sharply prismatic, with eight faces reticulated by

Digitized by Google

spicular threads and rarely ornamented with inconspicuous nodes. Found as internal molds.

Characteristic of the Chemung and occurs also in the upper Portage and the Keokuk.

5. **P. prismatica** Hall. (Fig. 24.) Upper Devonic.

Often without perceptible expansion for a considerable distance but usually expanding to an aperture whose diameter is the greatest

FIG. 24. *Prismodictya prismatica* (after Hall).

FIG. 25. *Hydnoceras tuberosum* (after Hall).

width of the sponge. Sometimes curved or twisted. Prism faces flat and each marked with one or two clearly defined spicular threads and other minor ones.

Chemung of New York, Pennsylvania.

Digitized by Google

V. HYDNOCERAS Conrad.

Obconical, more or less rapidly expanding from an acute base. Surface at first smooth except for the reticulated spicular threads, but soon developing eight prism faces and prominent nodes in horizontal and vertical rows. These nodes usually lie at the intersection of adjoining prism faces and are connected with one another in vertical rows by short prominent lamellæ. Occurs only as internal molds.

Characteristic of the Chemung. Occurs also in the Portage and Waverly.

6. **H. tuberosum** Conrad. (Fig. 25.) Upper Devonic.

Large. Transverse section usually subelliptical from compression. Horizontal rows of nodes not exceeding four or five in maturity and separated by broad concavities. Vertical rows eight and separated by concavities. Surface regularly reticulated by vertical and horizontal series of spicular bands.

Lower and Middle Chemung sandstones in New York.

FIG. 26. *Brachiospongia digitata*, reduced (Beecher's mem.).

VI. BRACHIOSPONGIA Marsh.

Skeleton enclosing a hollow central cavity which sends out large hollow arms, closed distally. Wall thin and bearing a net-work of spicules. Ordovicic.

7. **B. digitata** (Owen). (Fig. 26.) Ordovicic.

Arms eight to eleven, radiating from circumference of body; at first they pass off horizontally, then turning at right angles they rise nearly vertically. Size from six inches to one foot in diameter.

Trenton of Kentucky.

VII. ASTRÆOSPONGIA Roemer.

Thick-walled, bowl-shaped. Upper surface concave, lower convex, without traces of attachment. Skeleton composed of rela-

Digitized by Google

tively large, eight-rayed spicules, six of which are disposed in the same plane while the two projected at right angles to these are reduced to button-like prominence. Siluric.

8. **A. meniscus** Roemer. (Fig. 27.) Siluric.

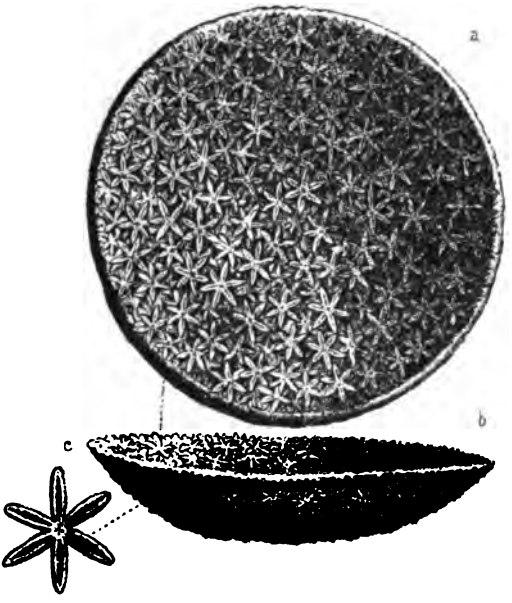


FIG. 27. *Astræospongia meniscus* with enlargement of spicule *c* (Roemer).

Vertical section crescent- (meniscus) shaped. Star-shaped spicules very conspicuous, especially on the concave surface.

Upper Siluric of Tennessee.

VIII. RECEPTACULITES Defrance.

Globular to platter-shaped bodies, containing a central cavity whose calcareous wall is composed of five-rayed spicules. Ord. to Dev.

9. **R. oweni** Hall. (Fig. 28.) Ordovicic.

Broad, varying in diameter from a few inches to two feet. Consisting of a flat, circular disc with a small, funnel-shaped central depression above, corresponding to the narrow projecting base of attachment on the under side. Cell rows curving strongly as they radiate from the center. Cell apertures quadrangular at surface, becoming circular and decreasing in diameter towards the center.

Digitized by Google

The characteristic fossil throughout the lead region, of the Galena limestone in Illinois, Iowa and Wisconsin.

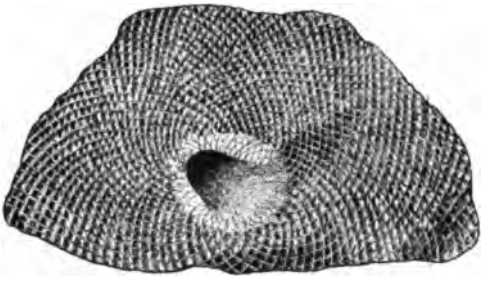


FIG. 28. *Receptaculites oweni* (Minn. Geol. Surv., Schuchert & Winchell).

10. **R. hemisphericus** Hall. Siluric.

Small, rarely exceeding two inches in diameter. Hemispherical or subglobular with truncated base. Cells in rows obliquely radiating from a sub-central point, minute near point of origin but rapidly increasing in size over the upper surface and again decreasing down the sides.

Niagara of Wisconsin.

11. **R. ohioensis** Hall & Whitfield. (Fig. 29.) Siluric.

Differs from *R. hemisphericus* in its smaller size, not exceeding one and one fourth inches in diameter, and in its smaller cells.

Niagara of Ohio.

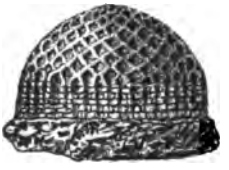


FIG. 29. *Receptaculites ohioensis* (Ohio Geol. Surv.).

12. **R. mamillaris** Walcott. Ordovicic.

Usually in form of an inverted cone with a deep depression above. In more expanded forms the center of the otherwise broadly rounded base extends as a short-pointed projection.

In upper portion of the Pogonip group (= Chazy) in Nevada.

13. **R. (Ischadites) iowensis** (Owen). (Fig. 30.) Ordovicic.

Base concave, upper surface, flatly dome-shaped, with an opening into the hollow cavity. Small rhomboidal cells opening on surface in curved rows, intersecting in arches.

Galena limestone of Iowa, Wisconsin and Minnesota.

Digitized by Google

PHYLUM III. CŒLENTERATA.

Class **Hydrozoa** Huxley.

This class comprises the modern hydroids, delicate moss-like animals, mostly growing in branching clusters or colonies having a common stem or a common base. A few simple forms occur in fresh water (*Hydra*), but with only one exception, the branching and clustered species are all marine. They are commonly found attached to the seaweed fringing our rocky shores, or growing in the deeper waters, though many also grow on rocks, where they are attached by a network of delicate root-like stolons, while others again are attached to shells or live partly buried in the mud.

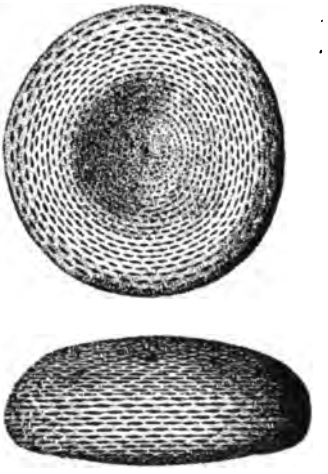


FIG. 30. *Ischadites iowensis* (Minn. Geol. Surv.).

Hydroids of the modern type are rare in the fossil state, but two aberrant groups the *Graptolites* and the *Hydrocorallines* are abundantly represented in American strata. It will be necessary, however, to briefly consider the characters of a modern hydrozoan in order to understand the essential characteristics of the extinct species. For this purpose, *Sertularia pumila* (Fig. 31), a type abundant on the rock-weed all along the north Atlantic coast, will be selected, since in its general form it suggests the characteristics of the *Graptolites*, though in reality quite distinct from them.

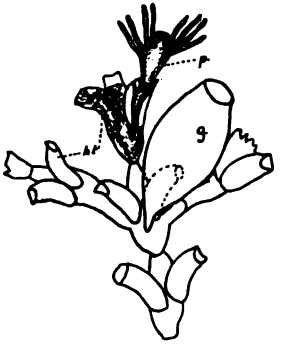


FIG. 31. *Sertularia pumila* Recent (after Nutting). *p, polyp; ht, hydrotheca; g, gonotheca* (much enlarged).

In general appearance this species resembles a delicate plant, consisting of branching stems furnished with a double row of opposite teeth, like those of a saw. Under the microscope it is seen that the organism consists of two essential parts, easily distinguished if the specimen is properly stained

Digitized by Google

and well mounted. In the center is the animal proper, consisting of an elongated hollow stem, from which at regular intervals arise a pair of opposite flower-like heads or *polyps*, connected with the stem by a narrow "neck." The polyps form the swollen end of each tube, which at the summit is contracted into a narrow opening, the mouth, and furnished some distance below the summit with a ring of *tentacles*. The hollow internal space or stomach cavity of each polyp is continuous through the "neck" with that of the main stem, which in turn through the hollow tube of the rootstock is continuous with that of other stems of the colony. At intervals peculiar large polyps without mouth or tentacles occur, which serve the function of reproduction. In some types of hydroids free-swimming medusæ or "jelly-fish" are produced by these reproductive or *gonopolyps*. Enveloping the rootstock, stems and branches is a transparent membrane composed of the organic substance "chitin," which is similar to the material of which sponges consist. This envelope or *periderm* widens around the polyps into cups or *hydrothecæ*, into which the polyps can withdraw by muscular contraction, after which the opening is closed by a lid or *operculum*. In the figure one of the polyps is expanded, the others are contracted or not shown. The gonopolyps are surrounded by a bottle-shaped cup or gonotheca, which has a short neck and broad opening. The substance of the periderm is such that it may be preserved in the form of a carbonaceous film.

Graptolites.

The simplest groups of Graptolites (*Axonolipa*), characteristic of the highest Cambric and lower half of the Ordovicic, are derived by a succession of buddings from a primal hydrotheca known as the *sicula*. If the first two buds extend in opposite directions, the result is a type with branches composed of a single row of hydrothecæ. These may be strung out in long rows, where each succeeding hydrotheca buds from near the margin of the preceding one (Fig. 46), or they may bud rapidly so as to overlap each other. In the former case the serrations are far apart; in the latter, which is the more specialized, they are close together. When the first two buds give off two buds each, four branches result (*Tetragraptus*) instead of two (*Didymograptus*). If later buds again give off two instead of one bud, a larger number of branches is produced (*Staurograptus*, *Dichograptus*, etc.). When the branches are numerous and united by cross-bars or *dissepiments* a net-like struc-

Digitized by Google

ture is produced (*Dictyonema*). When the original buds from the sicula are completely turned back upon themselves, so as to open in the opposite direction from the sicula, and grow together, back to back, a double-rowed structure is produced with hydrothecæ on opposite sides of the median line. Types of this kind (*Diplograptus*, *Climacograptus*) are reënforced by a median axis or rod, the *virgula*, which extends the entire length of the branch and beyond the last-formed hydrothecæ. It generally appears as a shining, solid rod, extending beyond the hydrothecæ. A number of types with a single row of hydrothecæ also possess a virgula. Types possessing this structure are classed in a division by themselves (*Axonophora*). In all cases the colony derived by budding from a single sicula is called a *rhabdosome*, whether consisting of one (single- or double-rowed) or many (single-rowed) branches. In many cases a number of rhabdosomes may be united by the ends of their virgulæ (that farthest away from the sicula), forming a compound rhabdosome, which in some cases is provided with a float or air-bladder-like structure, from the base of which also depend the gonangia or reproductive sacs (*Diplograptus*). (Fig. 54.)

While some of the *Graptolites* were probably attached to seaweeds like modern hydroids, others were free-floating or *planktonic* organisms. This and the fact that sea weeds when torn from their anchorage would also float, explains the wide distribution of the *Graptolites* and their presence in rocks of the same age in widely separated parts of the world. They are best preserved in fine mud-rocks, especially the black shales. They have, however. been found in limestones (calcilutytes) and even in sandstones, They are excellent index fossils of the lower Palæozoic rocks.

Literature.

Some of the more important works on American *Graptolites* are:

1865. **Hall, James.** Graptolites of the Quebec group. Canadian Organic Remains Decade II., Geol. Surv. Canada.

1868. **Hall, James.** Introduction to the Study of the Graptolites. N. Y. State Cab. Nat. History, 20th Ann. Report.

1879. **Spencer, J. W.** Graptolites of the Niagara Formation. Can. Naturalist, 1878–79, p. 457.

1884. **Spencer, J. W.** Graptolites of the Upper Silurian System. Mus. Univ. Missouri Bulletin.

Digitized by Google

1892. Gurley, R. R. The Geologic Age of the Graptolite Shales of Arkansas. Ark. Geol. Surv. Ann. Rep., 1890, 3: p. 401.

1895. Matthew, G. F. Two New Cambrian Graptolites with Notes on Other Species of Graptolitidæ of That Age. N. Y. Acad. Sci. Trans., Aug., 1895.

1896. Gurley, R. R. North American Graptolites. Jour. Geol., Vol. 4, no. 1, p. 63; no. 3, p. 291.

1904. Ruedemann, R. Graptolites of New York. Part 1. N. Y. State Museum Memoir, 7.

[This is the most comprehensive and most important work that has appeared in this country since Hall's Graptolites of the Quebec Group.]

KEY TO THE GENERA.

I. DENDROIDEA. Rhabdosomes irregularly branching in a shrub-like funnel or fan-like manner. Hydrothecæ mostly in the form of pits, rarely prominent.. *A.*

A. Branches joined at frequent intervals ..... 1.

1. Branches joined by cross-bars or dissepiments..... I. *Dictyonema.*

1. Branches flexuous, coalescing at points of contact; dissepiments rare. II. *Desmograptus.*

A. Branches not joined, or only at great intervals ..... 2.

2. Branches diverging ..... *aa.*

aa. Branches stout, bifurcating, irregularly dendroid. III. *Dendrograptus.*

aa. Branches plumose, with branchlets arranged alternately on opposite sides ..... IV. *Ptilograptus.*

2. Branches parallel, bifurcating at intervals ..... Callograptus.

II. GRAPTOLOIDEA. Rhabdosomes simple or branching but not shrub-like. Hydrothecæ commonly distinctly marked ..... *B.*

B. AXONOLIPA. Virgula absent..... 3.

3. Branches with single row of hydrothecæ (monoprionidian)..... *bb.*

bb. Branches of rhabdosomes bifurcating at irregular intervals, numerous ..... *k.*

k. Branches apparently four at center, making a cross. V. *Staurograptus.*

k. Branches two at center..... *x.*

x. Primary branches S-shaped ..... VI. *Cœnograptus.*

x. Primary branches not S-shaped..... Bryograptus.

bb. Branches of rhabdosome regularly bifurcating..... *l.*

l. Branches more than 8..... *y.*

y. Three bifurcations (sometimes more) producing 16 branches. VII. *Loganograptus.*

y. Numerous bifurcations, regularly alternating. VII. *Goniograptus.*

l. Branches 8 or less ..... *z.*

z. Branches 8, sometimes 6 ..... VII. *Dichograptus.*

z. Branches 4..... VIII. *Tetragraptus.*

z. Branches 2..... X. *Didymograptus.*

Digitized by Google

3. Branches leaf-like, four rows of hydrothecæ, generally appearing as two rows from compression ..... IX. *Phyllograptus.*

B. AXONOPHORA. Virgula present ..... 4.

4. Branches with a single row of hydrothecæ or only partly with double row *cc.*

cc. Branches entirely distinct, only a single row of hydrothecæ (Monoprionidian) opening in a direction opposite to the sicula. XV. *Monograptus.*

cc. Two branches, more or less united ..... *m.*

m. Branches united only at base, V-shaped with hydrothecæ generally on outside ..... XIII. *Dicellograptus.*

m. Branches united for some distance, above the base, Y-shaped. XII. *Dicranograptus.*

4. Branches with double row of hydrothecæ throughout (Diprionidian).. *dd.*

dd. Periderm solid ..... *n.*

n. Hydrothecæ sharp .. .. XIV. *Diplograptus.*

n. Hydrothecæ blunt ..... XI. *Climacograptus.*

dd. Periderm a fine meshwork ..... XVI. *Retiolites.*

SYNOPSIS OF GENERA AND SPECIES.

ORDER I. DENDROIDEA Nicholson.

I. DICTYONEMA Hall.

Rhabdosomes forming funnel or fan-shaped fronds, composed of numerous bifurcating branches arising from an acute base, and united at intervals by thin cross bars or dissepiments. Hydrothecæ seldom well preserved, of several types, appearing occasionally as teeth or as pits on the side of the branches turned toward inside of the funnel. Camb.–Dev.

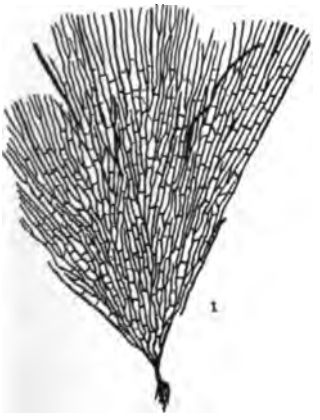


FIG. 32. *Dictyonema flabelliforme* (after Matthew).

1. **D. flabelliforme** (Eichwald). (Fig. 32.) Upper Cambric.

Rapidly expanding cones up to ten or twelve inches in length. Branches about .4 mm. wide, subparallel, rigid, bifurcating at long intervals, separated by a little over 1 mm. Dissepiments about half as thick as the branches.

In the shales forming the uppermost Cambric beds of eastern North America (especially in eastern Canada) and widely distributed in Europe.

Digitized by Google

2. **D. retiforme** Hall. (Fig. 33.) Mid-Siluric.

Broadly funnel-shaped. Branches rather coarse, frequently bifurcating, marked externally by flexuous striæ. Dissepiments

FIG. 33. *Dictyonema retiforme* (N. Y. State Mus. Rep.).

thin, diameter about a fourth that of the branches; rather oblique and numerous.

In the Rochester shale (Niagaran) of New York and Canada.

3. **D. gracilis** Hall. (Fig. 34.) Mid-Siluric.

FIG. 34. *Dictyonema gracilis* (N. Y. State Mus. Rep.).

Digitized by Google

Branches very slender, bifurcating and slightly diverging, irregularly striated or indented. Dissepiments slender and distant.

Occurs with the preceding.

4. **D. hamiltoniæ**. Hall. (Fig. 35.) Mid-Devonic.

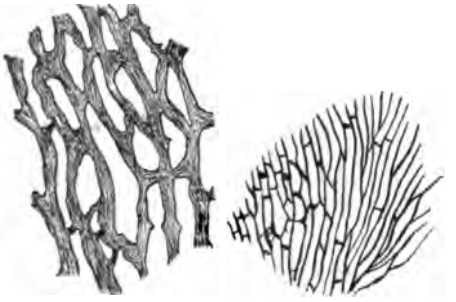


FIG. 35. *Dictyonema hamiltoniæ* with enlargement.

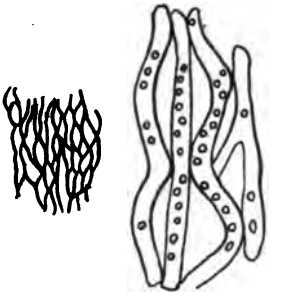


FIG. 36. *Desmograptus cancellatus* (Ruedemann, N. Y. State Mus. Mem.).

Branches slender, bifurcating, somewhat flexuous and uniting as in *Desmograptus*. Dissepiments scattered. (This may belong to the next genus.)

In the Hamilton shales of New York and in similar beds in Michigan.

II. DESMOGRAPTUS Hopkins.

Differs from *Dictyonema* in the flexuous character of the branches, which unite at intervals when they come in contact. Dissepiments chiefly in lower part of frond. Ord.–Dev.

5. **D. cancellatus** Hopkins. (Fig. 36.) Lower Ordovicic.

Branches 12 to 14 in 10 mm. forming long narrow meshes, twice as long as wide. Thecal apertures circular.

In shales of the age of the Lower Chazy in New York and Canada (?).

III. DENDROGRAPTUS Hall.

Rhabdosome with a strong main stem supporting a broad, spreading, shrub-like, variously ramifying frond. Hydrothecæ commonly obscure, or in the form of pits, sometimes well marked. Ordovicic.

6. **D. flexuosus** Hall. (Fig. 37.) Lower Ordovicic.

An inch or more in length, branches broadly and rather regularly diverging.

Digitized by Google

In shales of age of Beekmantown (*Tetragraptus zone*) of Canada and New York.

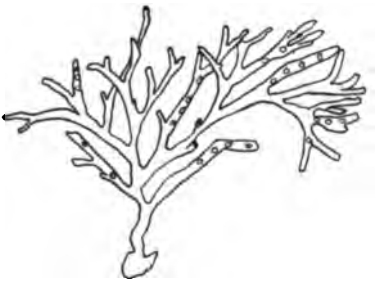


FIG. 37. *Dendrograptus flexuosus* (Ruedemann, N. Y. State Mus. Mem.).

IV. PTILOGRAPTUS Hall.

Rhabdosome with branches provided with two rows of alternate branchlets. No traces of thecal apertures have been found. Ord.–Sil.

7. **Pt. plumosus** Hall. (Fig. 38.) Lower Ordovicic. Branchlets slender, filiform and close set, diverging at about 40°, and about 3.5 mm. long.

In shales of the age of Lower Chazy, in Canada and New York.

FIG. 38. *Ptylograptus plumosus* (Hall, Can. Org. Rem.).

ORDER II. GRAPTOLITOIDEA Lapworth.

Suborder AXONOLIPA Frech.

V. STAUROGRAPTUS Emmons. (*Clonograptus* Hall.)

Rhabdosome cruciform at the center, owing to the rapid budding of the early hydrothecæ. Repeated bifurcations produce a large number of branches, hydrothecæ long and but slightly overlapping. Camb.–Ord.

8. **S. dichotomus** Emmons. (Fig. 39.)(*Clonograptus proximatus* Matthew). Upper Cambric. Branches upward of forty, the result of repeated bifurcation. Thecæ from 11 to 13 in 10 mm., in contact for a little over a third of their length. Apertures nearly vertical to axis.

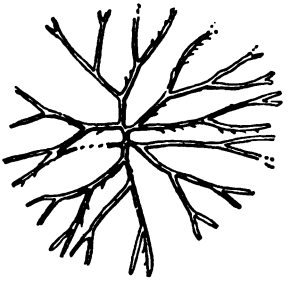


FIG. 39. *Staurograptus dichotomus* (after Matthew).

In the upper Cambric shales of eastern Canada and United States (*Dictyonema* shales).

Digitized by Google

VI. Cœnograptus Hall.

Bilaterally symmetric rhabdosome, the main stem (of tubular hydrothecæ) bent into an S with simple unicellular branches of similar structure given off from the convex side. The sicula appears at the center of the principal stem. Ordovicic.

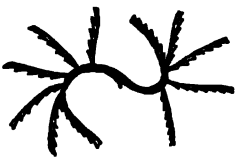


Fig. 40. *Cœnograptus gracilis.*

9. **C. gracilis** Hall. (Fig. 40.) Middle Ordovicic.

Slender stem, branches with fine serrations from crowding of the hydrothecæ, Normanskill shales, Hudson Valley, etc.

VII. Dichograptus Salter. (Including *Loganograptus* and *Goniograptus*.)

Rhabdosome of eight (typical) or more (*Loganograptus* and *Goniograptus*) large and narrow branches, united by a common stem in center which with the lobes of the branches lies within a central membranaceous disc. Branches with single row of hydrothecæ, becoming prominent some distance from center. When branches occur separated, they can only be determined by the form of their hydrothecæ. Ordovicic.

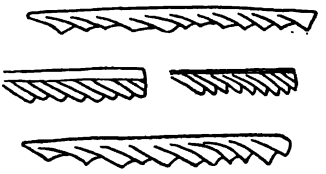


Fig. 41. *a* (upper), *Loganograptus logani; b* (middle left), *Tetragraptus quadribrachiatus; c, Dichograptus octobrachiatus: d* (lower), *Goniograptus thureaui* (all enlarged).

10. **D. octobrachiatus** Hall. (Fig. 41.) Lowest Ordovicic.

Eight, large and coarse branches often a foot long — central disk eight-angled.

Lower shales, Point Levis and Hudson River Valley, Beekmantown horizon. Also European.

11. **D. (Loganograptus) logani** Hall. (Fig. 41, *a*.) Lowest Ordovicic.

Numerous (thirteen to twenty-five, normally sixteen) slender branches up to nine inches long, symmetrically branching at base. Hydrothecæ become prominent only at some distance from base. Central disk many-angled.

Lower graptolite shales (Beekmantown), Point Levis and Hudson River Valley. Also European.

Digitized by Google

12. **D. (Goniograptus) thureaui** McCoy. (Fig. 41, *d*, 42.) Lower Ordovicic.

Four nearly rectangular main branches of a zigzag outline with regularly alternating secondary branches.

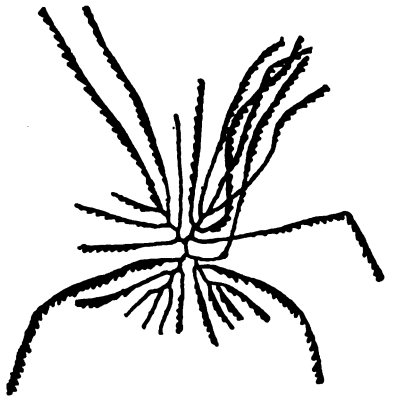


FIG. 42. *Goniograptus thureaui.*

Lower graptolite shales of Quebec and Hudson Valley (Beekmantown). Also European.

VIII. TETRAGRAPTUS Salter.

Typically of four short and broad branches with large hydrothecæ. A common transverse stem (funicle) occurs. A group still classed here is like a *Dichograptus* with only four arms, and a quadrangular central disk. It really belongs to a distinct genus. Ordovicic.

13. **T. bigsbyi** Hall. (Fig. 43.) Lower Ordovicic.

Of four short broad arms, with narrow but long hydrothecæ mucronate at the margin. Strong central stem.

Lowest graptolite beds (Beekmantown) of Point Levis and Hudson Valley.

FIG. 43. *Tetragraptus bigsbyi.*

14. **T. quadribrachiatus** (Hall). (Fig. 41, *b*.) Lower Ordovicic.

Like half a *Dichograptus octobrachiatus* — long slender branches with small hydrothecæ and a quadrate central disk.

Lower graptolite beds (Beekmantown) of Canada and Hudson Valley. Also Europe.

IX. PHYLLOGRAPTUS Hall.

Like *Tetragraptus* with the four branches grown together, each two back to back, forming a cross in section — generally preserved in flattened form so as to appear as a single leaf-like body. Ordovicic.

15. **P. typus** Hall. (Fig. 44.) Lower Ordovicic.

Broad, oval to lanceolate, as appearing on shale, with 24 (22–26)

Digitized by Google

hydrothecæ to an inch. Broad axis or midrib, often crenulate or serrate.

Lower graptolite shale (Upper Beekmantown) Canada and Hudson Valley.

16. **P. ilicifolius** Hall. (Fig. 45.) Lower Ordovicic.

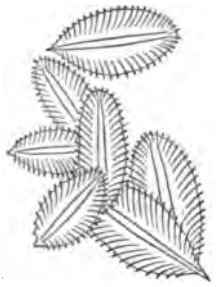


FIG. 44. *Phyllograptus typus* (after Roemer), enlarged.

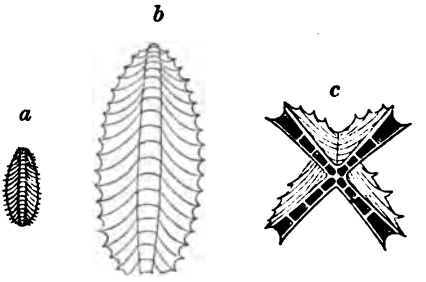


FIG. 45. *Phyllograptus ilicifolius.* *a*, natural size; *b*, enlarged; and *c*, restored crosssection (after Roemer).

Differs from the preceding in its thicker substance, proportionally shorter and broader form, more closely arranged hydrothecæ (29–32 to an inch) and strongly mucronate or spinous lower lip of hydrothecæ.

Shales of Middle Beekmantown age, Canada and New York.

17. **P. angustifolius** Hall. (Fig. 46.) Lower Ordovicic.

Narrow elongate form, generally a little broader at the base. Thecæ strongly mucronate on lower sides. Lower shales (Beekmantown) of Point Levis and Hudson Valley.

18. **P. anna** Hall. Lower Ordovicic.

More nearly rounded, often truncated, numerous thecæ. Higher Beekmantown and Lower Chazy horizon.

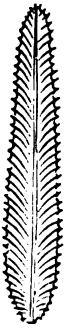


FIG. 46. *Phyllograptus angustifolius*, enlarged (after Roemer).

X. DIDYMOGRAPTUS McCoy.

Rhabdosome consisting of two symmetrical branches diverging from the basal cell (sicula) at angles from 10° to 180° or over, with oblique hydrothecæ opening inwards. Ordovicic.

Digitized by Google

19. **D. bifidus** Hall. (Fig. 47, *c*, 48.) Lower Ordovicic.

Divergence of branches 15° to 20°, gradually widening through increase in length of hydrothecæ to about two thirds distance from

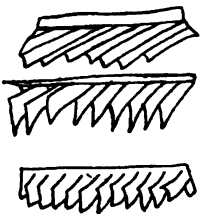


FIG. 47. *a* (upper), *Didymograptus nitidus*; *b*, *D. patulus*; *c* (lower), *D. bifidus* (all enlarged).

FIG. 48. *Didymograptus bifidus.*

base, then narrowing again to apex. Shales of upper Beekmantown age (Deep Kill), Point Levis and Hudson Valley.

20. **D. nitidus** Hall. (Fig. 47, *a*, 49, *a*.) Lower Ordovicic.

Thecæ closely arranged, margin slightly concave, rectangular to axis of theca. Branches with wide angle of divergence (nearly or quite 180°). Lower Ordovicic of Point Levis and Hudson Valley (Beekmantown).

21. **D. patulus** (Hall). (Fig. 47, *b*, 49, *b*.) Lower Ordovicic.

FIG. 49. *a* (upper), *Didymograptus nitidus*; *b*, *Didymograptus patulus.*

Differs from *D. nitidus* in its wider and more rapidly widening branches, with ends of hydrothecæ concave and strongly acute instead of rectangular.

Lower graptolite shales (Beekmantown) of Point Levis and Hudson Valley.

Suborder AXONOPHORA Frech.

XI. CLIMACOGRAPTUS Hall.

Simple rhabdosomes, with parallel hydrothecæ, their outer margin straight and parallel to the axis of the stem. Ordovicic.

Digitized by Google

22. **C. bicornus.** (Fig. 50, 51, *a*.) Middle Ordovicic.

Gradually widening upwards, hydrothecæ approaching rectangular outline, base with two diverging mucronate points.

Normanskill shales (Trenton) of Hudson Valley, and equivalent beds of the Cincinnati region.

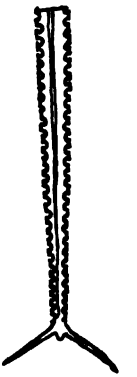


FIG. 50. *Climacograptus bicornis* (slightly enlarged).

23. **C. typicus** Hall. (Fig. 51, *b*.) Upper Ordovicic.

Differs from preceding in narrow almost horizontal incisions between, and small mucronate point at base of hydrothecæ.

Utica Slate of New York and Cincinnati region.

XII. DICRANOGRAPTUS Hall.

Lower portion of hydrosome biserial, upper portion dividing into two uniserial branches.

Form Y-shaped. Hydrothecæ as in *Climacograptus*. Ordovicic.

24. **D. ramosus** Hall. (Fig. 52.) Middle Ordovicic.

Undivided portion long, incisions between hydrothecæ deep, the latter with mucronate points.

Normanskill shales (Trenton), Hudson Valley. Europe.

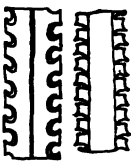


FIG. 51. *a* (left), *Climacograptus bicornus*; *b*, *C. typicus* (enlarged).

XIII. DICELLOGRAPTUS Hopkins.

Like the preceding, but divided to the base. V-shaped. Ordovicic.

25. **D. complanatus** Lapworth. (Fig. 53, *a*, *b*.) Middle Ordovicic.

Diverging at angle of 30–50 degrees. Hydrothecæ narrow and very oblique; non-mucronate.

Normanskill shales (Trenton), Hudson Valley.

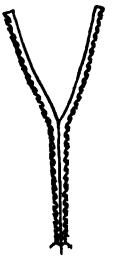


FIG. 52. *Dicranograptus ramosus* (slightly enlarged).

26. **D. divaricatus** Hall. (Fig. 53, *c*.) Middle Ordovicic

Diverging at angle of over 90°, up to 130°;

Digitized by Google

hydrothecæ furnished with slightly incurved hook-like projections on the upper outer region; 3 basal spines.

Normanskill shales (Trenton), Hudson Valley.

27. **D. sextans** Hall. (Fig. 53, *d*, *e*.) Middle Ordovicic.

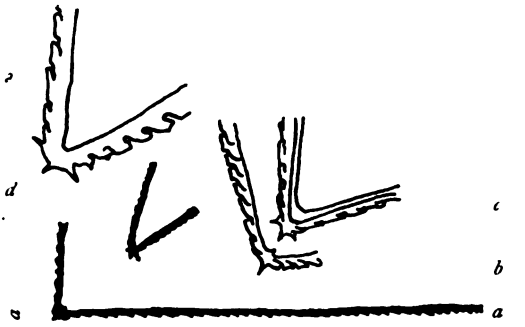


FIG. 53. *a*, *Dicellograptus complanatus*; *b*, same, enlarged; *c*, *D. divaricatus* (enlarged); *d*, *D. sextans*; *e*, same enlarged.

Similar to preceding, but basal spines turned up and outward.

Normanskill shales (Trenton), Hudson Valley.

XIV. DIPLOGRAPTUS McCoy.

Rhabdosomes linear to leaf-like, with two rows of alternating oblique hydrothecæ. Virgula prolonged beyond the proximal end and in perfect colonies attached with others to a floating (?) central disk. Ordovicic.

28. **D. pristis** Hisinger. (Fig. 54.) Upper Ordovicic.

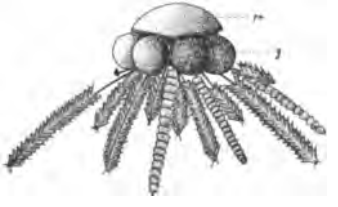


FIG. 54. *Diplograptus pristis*. Restoration of colony by Ruedemann. *pn*, pneumatophore or swimming bladder; *g*, gonangia (N. Y. St. Geol. Rept.).

Large oblique, aeutc serrations, pointed exteriorly, three basal spines, the central one usually longest.

Utica slate of New York and other states and Canada. Europe.

29. **D. foliaceus** Murchison.

Middle and Upper Ordovicic.

Hydrothecæ more oblique, smaller and more numerous than *D. pristis*.

Normanskill shales (Trenton), Hudson Valley. Europe.

Digitized by Google

30. **D. whitfieldi** Hall. Middle Ordovicic.

Like *D. pristis*, but hydrothecæ with spinose prolongations, and base with a single spine.

Normanskill shales (Trenton) of Hudson Valley.

31. **D. dentatus** Brongniart. (= *D. pristiniformis* Hall.) Lower Ordovicic.

Narrow slender stipes with closely crowded, very oblique hydrothecæ.

Graptolite shales of Point Levis and Hudson Valley. Lower Chazy. Europe.

XV. Monograptus Geinitz.

Rhabdosomes with only a single row of hydrothecæ, which in the American form are drawn out into bent points, at the apices of which are the openings. Silur.–Dev.

32. **M. clintonensis** Hall. (Fig. 55, *b*.) Middle Siluric.

Stipes straight with well-marked virgula. Ends of hydrothecæ bent over so that apertures open downward. Clinton shales of Rochester, N.Y.

XVI. Retiolites Barrande.

Rhabdosome with the periderm attenuated and supported on a meshwork of fibers. Hydrothecæ in two rows, opening outward. Two virgulæ attached to opposite sides, in the median plane. Ord.–Sil.

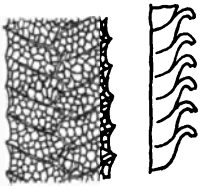


Fig. 55. *a* (left), *Retiolites venosus*; *b*, *Monograptus clintonensis* (both enlarged).

33. **R. venosus** Hall. (Fig. 55, *a*.) Mid-Siluric.

Hydrothecæ slightly oblique; apertural margin concave; periderm very tenuous.

In the Clinton shales of western New York, associated with the preceding.

Hydrocorallines.

Stromatoporoidea Nicholson and Murie.

The Stromatoporoids are extinct organisms wholly confined to the Palæozoic, where they were extremely important reef-builders, much of the limestone of the Siluric and Devonic resulting from the destruction of reefs of these fossils. They are most closely related to the modern Hydrocorallines (Millepora) and to Hydrac-

Digitized by Google

tinia, an aberrant type of Hydroid. This latter will serve to elucidate the structure of the Stromatoporoids.

Hydractinia (Fig. 56) commonly grows as an incrustation on the shells of dead gastropods, which have been seized as a habitation by hermit crabs. It is also found, however, encrusting rocks. The polyps are naked, *i. e.*, not protected by hydrothecæ, and of several kinds. The ordinary feeding polyp or nutritive zoöid has a mouth and tentacles. A second type of polyps has short, club-shaped tentacles and bears a cluster of reproductive buds or gonangia. These are the gonopolyps. A third and sometimes a fourth order of polyps occur, scattered about or confined to certain regions. These have an offensive and defensive function and apparently warn the colony of approach of danger.

FIG. 56. *Hydractinia* (Recent), showing 3 types of polyps arising from spinous hydrophyton (enlarged).

The colony secretes a basal horny or calcareous structure, the *hydrophyton*, which consists of successive, slightly separated, horizontal laminæ, supported by numerous vertical columns known as *radial pillars* (Fig. 57). From the surface arise hollow spines and tubercles, which serve as a protection when the polyps are contracted below their summits. The spaces between the laminæ communicate with the surface by means of tubes, and branching grooves or *astrorhizæ* are commonly present on the surface. In *Millepora* the colony secretes a calcareous structure (*cœnosteum*) not unlike some coral masses. This consists of a network of calcareous fibers and is traversed at frequent intervals by large tubes surrounded by a ring of smaller ones. The larger tubes (gastropores) lodge feeding polyps, and the smaller (dactylipores) lodge fighting polyps. Both sets of tubes are divided in the older part by horizontal partitions or tabulæ.

FIG. 57. *Hydractinia.* Cross-section of hydrophyton through a spine, showing horizontal laminæ and radial pillars.

The extinct Stromatoporoids combine the characteristics of the two types outlined above. They consist of hemispherical, spreading, encrusting, columnar, or nearly globular calcareous structures sometimes attaining a diameter of five feet or over, or a length of

Digitized by Google

ten feet (*Beatricea*). The base is generally covered by a concentrically wrinkled calcareous crust or *epitheca*. In structure these bodies recall the hydrophyton of *Hydractinia* as described above, consisting of numerous concentric undulating calcareous laminæ, separated by interspaces, and supported by *radial pillars*. Both laminæ and supporting pillars are traversed in most cases by minute canals, and in some types vertical "zoöidal tubes" with tabulæ occur, as in *Millepora*. The surfaces of the laminæ are marked by numerous pores, the openings of canals, and by tubercles, blunt rounded prominences or "mamelons," or blunt spines, and shallow furrows radiating from a center (*Astrorhizæ*). In some types (*Actinostroma*) the laminæ are composed of a network of calcareous rods disposed in a horizontal series. In some cases the horizontal and vertical elements are so fused as to form a dense reticulated tissue, when the separate components are with difficulty distinguishable (*Stromatopora*). Frequently the horizontal laminæ are combined into strata or "latilaminæ" of some thickness, separated from each other by a slight interspace.

Several species of Stromatoporoids encrust cylindrical corals (*Aulopora*, *Syringopora*, *Ceratopora*, etc.) which become completely immersed in the Stromatoporoid, opening only on the surface in circular orifices. These orifices were formerly thought to be a structural part of the Stromatoporoid and the name Caunopora was applied to these types. Similar commensalism occurs in some Bryozoa.

LITERATURE.

1866. **Winchell, Alexander.** On the structure and affinities of the Stromatoporoids. Proc. Amer. Assoc. Adv. Science, 1866, p. 91.

1873. **Hall, James, and Whitfield, R. P.** Description of new species of fossils. 23d Ann. Report N. Y. State Cabinet, pp. 226–228, pl. 9.

1874. **Nicholson, H. A.** Palæontology of the Province of Ontario.

1875. ——— Palæontology of Ohio, Vol. II.

1878. **Nicholson & Murie.** The minute structure of the skeleton of Stromatopora and its allies. Journ. Linn. Soc., Vol. 14.

1878. **Quenstedt.** Petrefacten Kunde Deutschlands. Schwämme, pl. 141 and 142.

1884. **Spencer, J. W.** Stromatopoids. Bull. Mus. University of State of Missouri, 1, 43–52.

1886. **Nicholson, H. A.** On some new or imperfectly described species of Stromatoporoids. Ann. and Mag. of Nat. Hist., Ser. 5, Vol. 17, p. 225; Vol. 18, p. 8, Vol. 19, p. 1.

Digitized by Google

1891. Same, part IV., do., ser. 6, Vol. 7, p. 309.

1886–92. **Nicholson, H. A.** A monograph of the British Stromatoporoids. Palæontographical Society monograph.

1894. **Girty, G. H.** Revision of the sponges and cœlenterates of the Lower Helderberg Group of New York. 14th Ann. Rept. N. Y. State Geol., p. 289, Stromatoporoidea.

Two keys are herewith given. The first is based on the microscopic structure and requires thin sections. It is believed that by its means most species may be traced to their proper genus. The other is based on external characters and is given to make possible field determination of the more important species of "Stromatopora" in the old sense. It applies only to the species described.

I. KEY TO THE GENERA.*

A. Calcareous tissue a meshwork of horizontal and vertical rectangular elements..... I.

I. Structure an open meshwork, radial pillars distinct, horizontal laminæ of calcareous anastomosing bars..... *.

*. Radial pillars continuous through a number of laminæ and interlaminar surfaces..... I. *Actinostroma.*

*. Radial pillars discontinuous..... II. *Clathrodictyon.*

I. Structure an open meshwork, radial pillars very large, horizontal elements thin irregular plates..... VII. *Labechia.*

I. Structure a dense reticulate meshwork in tangential section, but more open in vertical section, the radial pillars distinguishable..... **.

** Form spherical, massive or expanding..... aa.

aa. Laminæ bending upwards at regular intervals, forming a series of vertical rod-like structures passing through the mass. III. *Stylodictyon.*

aa. Laminæ not bending upwards, short irregular zoöidal tubes. IV. *Stromatoporella.*

** Form cylindrical and commonly branching, numerous well developed tabulate zoöidal tubes opening by circular pores..... V. *Idiostroma.*

I. Structure a dense reticulate meshwork in both tangential and vertical sections, radial pillars generally not distinct..... ***.

*** Structure reticulate, tabulate zoöidal tubes well developed. VI. *Stromatopora.*

*** Structure very dense, but vertical and horizontal elements distinguishable. VI. *Syringostroma* under *Stromatopora.*

B. Calcareous tissue of concentric laminæ, no vertical pillars..... II.

II. With vertical tubes..... VII. *Stromatocærium.*

II. Without vertical tubes..... VIII. *Cryptozoön.*

C. Calcareous tissue a single layer covered with a basal epitheca and with numerous blunt tubercles on the surface..... IX. *Labechia* (young).

D. Calcareous tissue a series of vesicles, form columnar..... X. *Beatricea.*

* Based on microscopic structure.

Digitized by Google

II. Key to the Species of "Stromatopora" in the Old Sense Based Chiefly on External Characters.*

A. Form a flattened or undulating expansion, generally with a basal epitheca..... *.
* Free or only attached at initial point..... *a.*
a. Surface with mamelons..... *aa.*
aa. Mamelons prominent ; astrorhizæ present though inconspicuous, surface granulate..... 9. *S. granulata* Dev.
aa. Mamelons low, astrorhizæ absent ..... 1. *S. expansa* Dev.
a. Surface sometimes undulated, with tubercles instead of mamelons ; no astrorhizæ..... *bb.*
bb. Tubercles of two sizes, the larger with pores. 10. *S. tuberculata* Dev.
bb. Tubercles minute, in rows, with pores between rows.
5. *S. striatella* Sil.
bb. Tubercles scattered, meshwork very coarse..... 7. *S. cellulosa* Dev.
a. Surface without mamelons or tubercles..... *cc.*
cc. Astrorhizæ well developed..... 2. *S. fenestrata* Dev.
cc. Astrorhizæ small ..... 4. *S. vesiculosa* Sil.
* Encrusting other fossils. Tubercles instead of mamelons ; astrorhizæ present.
11. *S. incrustans* Dev.
B. Form massive, hemispheric or spherical..... **.
** Divided into strata or latilaminæ..... *b.*
b. Surface with mamelons ..... *cc.*
cc. Astrorhizæ well developed..... 14. *S. monticulifera* Dev.
cc. Astrorhizæ small ..... 1.
1. Mamelons sharp and conical ..... 3. *S. nodulata* Dev.
1. Mamelons low and rounded ; astrorhizæ minute.
17. *S. centrota* Lower Dev.
b. Surface with pustules instead of mamelons..... *dd.*
dd. Astrorhizæ small..... ..... 15. *S. pustulifera* Dev.
b. Surface without mamelons or pustules..... *ee.*
ee. Astrorhiza present ..... 2.
2. Vertical section shows only dense tissue ..... 16. *S. densa* Dev.
2. Vertical section shows minute tabulate tubes traversing the entire stratum..... 13. *S. antiqua* Sil.
ee. Astrorhiza absent ..... 18. *S. barretti* Lower Dev.
** Not divided into strata, or but imperfectly so..... *c.*
c. Surface without true mamelons..... *ff.*
ff. Astrorhiza absent..... ..... 3.
3. Surface finely granulated with pores between rows of granules.
5. *S. striatella* Sil.
3. Surface with pustules, formed by the ends of large vertical rods.
8. *S. columnaris* Dev.
3. Surface with pustules in regular diagonal lines, and large irregular nipple-like elevations ..... 6. *S. ostiolata* Sil.
c. Surface with conical mamelons, astrorhizæ small..... 3. *S. nodulata* Dev.
C. Form cylindrical or branching ..... ***.
*** Surface with prominent pointed tubercles..... *d.*
d. Branches with rounded ends, surface porous ..... 12. *S. cæspitosa* Dev.

* This is adapted only to the species here described. It does not include *Stromatocarium*, *Cryptozoön*, *Labechia* or *Beatricea*. Endings become feminine.

Digitized by Google

SYNOPSIS OF GENERA AND SPECIES.

I. ACTINOSTROMA Nicholson.

Laminæ consisting of a meshwork of fibers. Radial pillars more or less continuous throughout, subequally spaced and generally

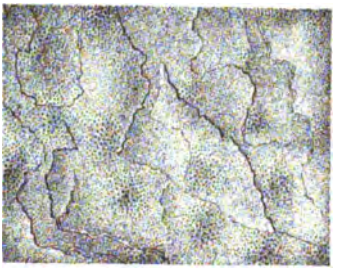


FIG. 58. *Actinostroma expansum*, surface. (N. Y. State Cab. Rep.)

FIG. 59. *Actinostroma fenestratum.* Vertical section × 8. (After Nicholson.)

projecting on the surface in the form of granules or tubercles. In vertical section the pillars and laminæ form a more or less regular series of rectangular meshes. Astrorhizæ present or absent. Siluric (rare)–Dev.

1. **A. expansum** (Hall & Whitfield). (Fig. 58.) Devonic.

Large expanding masses sometimes many feet in diameter,

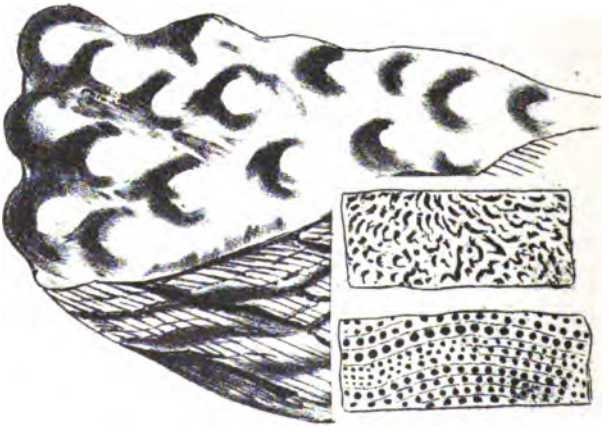


FIG. 60. *Actinostroma nodulatum* with horizontal and vertical sections. (Nicholson, Pal., Ohio.)

slightly undulating surface with low broad mamelons, three eighths to one half inch from center to center. Astrorhizæ absent.

In Upper Devonic rocks of Iowa and Canada.

Digitized by Google

2. **A. fenestratum** Nicholson. (Fig. 59.) Devonic.

Skeleton fibers coarser than preceding species — surface without the prominences (mamelons); astrorhizæ well developed.

In Devonic limestones of Manitoba, etc. Also European.

3. **A. nodulatum** (Nicholson). (Fig. 60.) Devonic.

In large expanding masses, with large sharp conical mamelons 12 mm. apart and small astrorhizæ.

Onondaga of Ohio.

II. Clathrodictyon Nicholson.

Laminæ a meshwork similar to preceding genus. Radial pillars discontinuous, extending only from lamina to lamina. Astrorhizæ

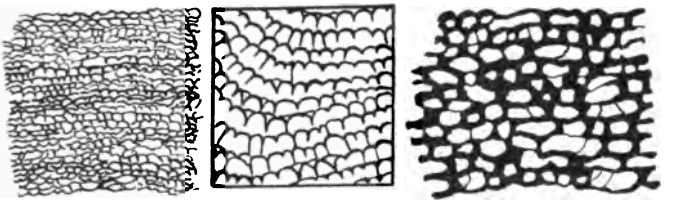


Fig. 61. *a*, *Clathrodictyon vesiculosum*, × 8; *b*, *Clathrodictyon striatellum*, × 8; *c*, *Stromatoporella granulata*, × 8. (All vertical sections.)

present. Vertical section often appearing vesiculose. Siluric (common)-Devonic (rare).

4. **C. vesiculosum** Nicholson & Murie. (Fig. 61, *a*, 62, 63.) Siluric.

Laminar expansions covered by a concentric basal epitheca; adult half a foot or more in diameter by an inch or more in greatest thickness. No rounded prominences; small astrorhizæ with centers from 3 to 5 mm. apart. Nine to eleven laminæ to 1 mm.

In the Clinton and Niagara of Ohio, Canada, New York and Anticosti. Also European.

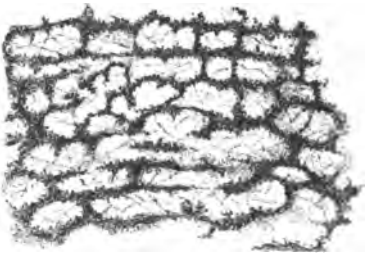


Fig. 62. *Clathrodictyon vesiculosum*, × 60. (After Nicholson.)

5. **C. striatellum** d'Orbigny. (Fig. 61, *b*.) Siluric.

Laminar or hemispheric with concentrically wrinkled epitheca. Surface undulating but no "mamelons," generally exfoliating con-

Digitized by Google

centrically around elevated areas. Numerous minute rounded tubercles, alternating with minute pores on well preserved surfaces. No astrorhizæ. Coarse (5 laminæ to 1 mm.) radial pillars like spines growing downward from bottom of laminæ.

FIG. 63. *Clathrodictyon vesiculosum* under or epithecal portion.

This is, according to Nicholson and Hinde, the common species of the Niagara of Canada, usually referred to as *Stromatopora concentrica*.

6. **C. ostiolatum** Nicholson. Siluric.

Differs from the preceding in the presence of nipple-like elevations of the entire mass at intervals, and in the occurrence of small perforated tubercles at regular intervals in diagonal lines.

In the Guelph of Canada and New York.

7. **C. cellulosum** Nicholson & Murie. (Fig. 64.) Devonic.

Differs from *C. vesiculosum* in the coarser meshwork (about 2 laminæ to 1 mm.) and in having the surface covered with tubercles or granules; and from *C. striatellum* in the coarser meshwork.

Onondaga limestone of Canada, New York, etc.

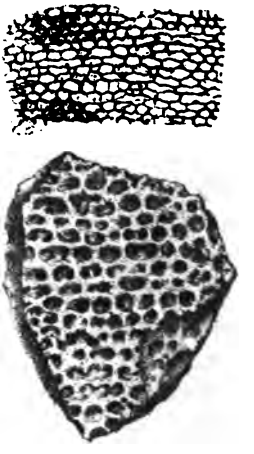


FIG. 64. *Clathrodictyon cellulosum*. (After Nicholson.)

III. STYLODICTYON Nicholson & Murie.

Cœnosteum a dense tissue traversed by numerous closely set circular vertical columns of large size, formed by the upward bending of the concentric laminæ. They terminate on the surface in small pointed eminences. Between the columns the tissue is more open, consisting of horizontal laminæ and vertical (radial) pillars, the latter often imperfect. Devonic.

8. **S. columnare** Nicholson. (*S. wortheni* Quenstedt.) (Fig. 65.) Devonic.

A large mass readily recognized by the vertical rods of dense tissue formed by the upward bending of the laminæ, and the small

Digitized by Google

rounded knobs in which the rods terminate on the surface, these being separated by a little more than half their diameter. Middle Devonic limestones of Ohio and Michigan (Traverse group).

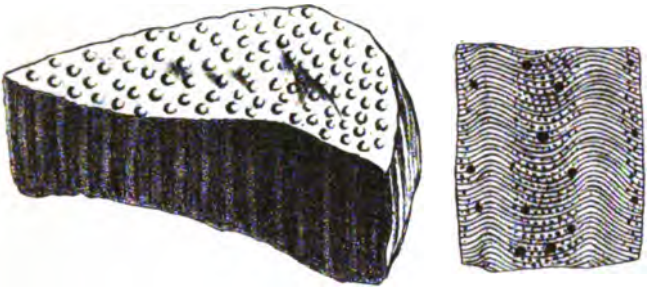


FIG. 65. *Stylodictyon columnare* with enlarged vertical section (Nicholson, Pal. Ohio).

IV. STROMATOPORELLA Nicholson.

Coralline mostly a lamillar expansion, furnished with a basal epitheca. Latilaminæ imperfect or not developed. In vertical section concentric lamellæ and radial pillars distinguishable. In tangential sections the ends of the pillars are distinguishable, while the general character of the tissue is reticulate; short irregular zoöidal tubes present. Devonic.

9. **S. granulata** Nicholson. (Fig. 61, *c*, 66.) Mid-Devonic.

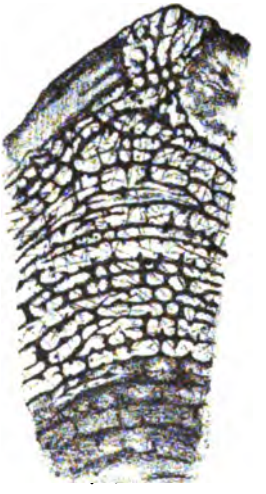


FIG. 66. *Stromatoporella granulata* enlarged vertical section.

FIG. 67. *Stromatoporella tuberculata* (after Nicholson).

Laminar expansions with concentrically wrinkled and striated epitheca. Thickness from 2 mm. up to 2 or 3 cm. Rather dis-

Digitized by Google

tant rounded mamelons pierced by apical pores, and with astrorhizæ inconspicuous. Surface covered with granules.

Common in the Hamilton formation of Canada.

10. **S. tuberculata** Nicholson & Murie. (Fig. 67, 68.) Mid-Devonic.

Differs from the preceding in absence of mamelons, the surface being undulating and covered only with tubercles of two sizes, and in coarser meshwork (about 6 laminæ to 2 mm.).

FIG. 68. *Stromatoporella tuberculata*, enlarged surface and section (after Nicholson).

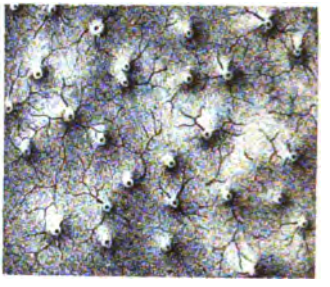


FIG. 69. *Stromatoporella incrustans* (N. Y. State Mus. Rep.).

In the Onondaga limestone of Canada and New York.

11. **S. incrustans** Hall & Whitfield. (Fig. 69.) Devonic.

Encrusting other fossils. Astrorhizæ with central tubercles pierced by pore.

Upper Devonic of Iowa and elsewhere.

V. IDIOSTROMA Winchell.

Form typically cylindrical, branching or growing in fascicles. Each branch has generally a tabulate tube, while other smaller tabulate zoöidal tubes with rounded openings are abundant. Radial pillars and concentric laminæ distinct. Surface with prominent pointed tubercles often arranged in ridges, or nearly smooth. Devonic.

12. **I. cæspitosum** Winchell. Mid-Devonic.

Branching irregularly; branches club-shaped.

Abundant in the limestones of the Traverse group (Hamilton) in Michigan.

Digitized by Google

VI. STROMATOPORA Goldfuss.

Massive or laminar. Laminæ grouped in strata or "latilaminæ"; radial pillars numerous, extending across a stratum and uniting with the laminæ to form a finely reticulated tissue as seen in vertical section. Tabulate zoöidal tubes, and astrorhizæ present. *Syringostroma* differs chiefly in its denser structure and somewhat more distinct horizontal and vertical elements. Silur. (rare)–Devonic.

FIG. 70. *Stromatopora antiqua*, vertical sections, the lower, × 2 (after Nicholson).

13. **S. antiqua** Nicholson & Murie. (Fig. 70.) Siluric.

Massive, spheroidal or hemispheric, with well-marked strata or latilaminæ 5 or 6 to 1 cm. Delicate zoöidal tubes traversing entire stratum. Astrorhizal centers 4–5 mm. apart, mamelons absent.

Niagara limestone of Canada and New York.

14. **S. (Cœnostroma) monticulifera** Winchell. Devonic.

In large hemispheric or globular masses, surface with large mamelons and astrorhizæ; centers 7.6 to 10 mm. apart. Extremely abundant in the Traverse (Hamilton) group of Michigan.

15. **S. pustulifera** Winchell. Devonic.

Similar to preceding, but surface with pustules instead of mamelons and smaller astrorhizal centers, 4 mm. apart.

Occurs with the preceding.

16. **S. (Syringostroma) densa** Nicholson. (Fig. 71.) Mid-Devonic.

Surface without mammillæ but well developed astrorhizæ. Structure exceedingly dense.

Onondaga of Ohio and probably elsewhere.

Digitized by Google

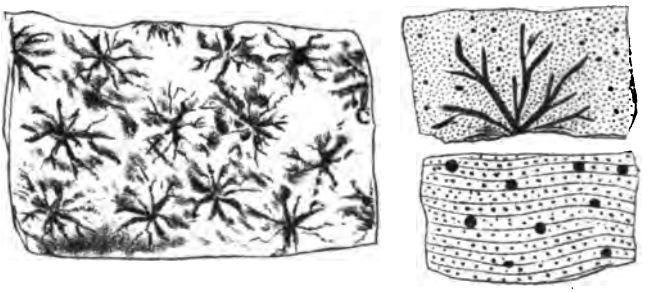


FIG. 71. *Syringostroma densum* with horizontal and vertical sections, enlarged (Nicholson, Pal. Ohio).

17. **S. (Syringostroma) centrota** Girty. (Fig. 72, *a*, upper sections.) Lower Devonic.

Spheroidal, surface with rounded mamelons and minute astrorhizæ.

Lower Helderberg of New York.

18. **S. (Syringostroma) barretti** Girty. (Fig. 72, *b*, lower sections.) Lower Devonic.

Hemispheric with flat base, surface without mamelons or astrorhizæ. Laminæ flexed in wave-like manner.

Lower Helderberg of New York.

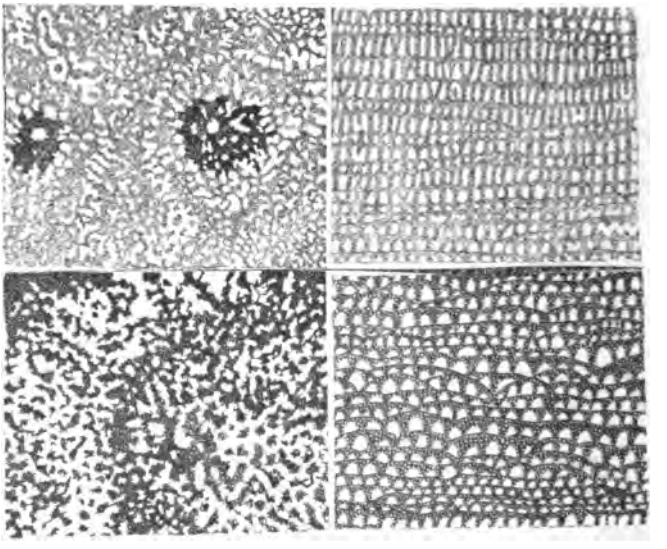


FIG. 72. *a* (upper two), *Syringostroma centrotum*, tangential and vertical sections; *b* (lower two), *Syringostroma barretti*, tangential and vertical sections (Girty in N. Y. State Mus. Report), enlarged × 10.

Digitized by Google

VII. Stromatocœrium Hall.

Cœnosteum massive, of dense, thick horizontal and concentric discontinuous laminæ, separated by very narrow interspaces. No radial pillars. Small vertical tubes penetrate the several laminæ, connecting interlaminar spaces. No astrorhizæ. Ordovicic.

19. **S. rugosum** Hall. Middle Ordovicic.

Hemispheric, with wrinkled concentric laminæ, and faint indications of vertical tubes.

Black River limestone, New York, Canada, etc.

20. **S. eatoni** Seely. Lower Ordovicic.

Expanding masses two inches or more in thickness, surface with mamelons. On weathered surfaces numerous concentric rings appear around the mameions.

Chazy of Lake Champlain.

VIII. Cryptozoön Hall.

Cœnosteum of irregular concentric laminæ, traversed by minute canals which branch and anastomose irregularly. No astrorhizæ. Camb.–Ord.

21. **C. proliferum** Hall. Lower Ordovicic.

Grows in compressed spherical cakes a foot or more in diameter.

In the Beekmantown horizon of New York, etc.

IX. Labechia E. & H.

Expanded, with a basal epitheca, vertical pillars a series of blunt tubercles in the young form, connected in adult by thin calcareous plates. Differs from *Actinostroma* in the large size of the pillars which are connected by plates instead of fibers. Ord.

22. **L. ohioensis** Nicholson. (Fig. 73.) Ordovicic.

Fig. 73. *Labechia ohioensis*, × 9.

Laminar or encrusting. Surface often with mamelons and with minute tubercles. Radial pillars distant, interspaces vesicular.

Upper Cincinnati beds of Ohio, Indiana, Canada, etc.

X. Beatricea Billings.

Cylindrical or angulated stems, often fluted and ranging in size to over ten feet in length and a foot in diameter. A central tube

Digitized by Google

with cystose tabulæ and a peripheral vesicular structure characterize the fossil. Ordovicic.

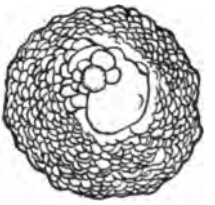


FIG. 74. *Beatricea nodulosa*, transverse section showing inner tube and cystose character (after Nicholson).

23. **B. nodulosa** Bill. (Fig. 74.) Ordovicic.
Cylindrical, with oblong, oval or subtriangular blunt-pointed tubercles, sometimes arranged in vertical rows.
Trenton and Cincinnati groups Anticosti and Kentucky.

24. **B. undulata** Bill. Ordovicic.
Surface sulcated longitudinally by short, irregular, wave-like furrows, from two lines to one inch across, according to size of specimen.
Cincinnati group of Anticosti.

Class **Anthozoa** or **Actinozoa** (Corals).

Marine animals ranging from low water to depths of 1,500 fathoms, but chiefly at home in tropic seas above the fifty fathom line. The animal or polyp may be simple, or give rise by budding or division to a compound polyparium, in which the individuals or polypites may be distinct or confluent.

The corallum or hard structure secreted by these animals is simple or compound. Typically each coral is furnished with a circumferential wall, and radiating lamellæ or *septa*, though either the one or the other may be much reduced or even absent. The wall may be an independent structure, growing up like the septa from the bottom of the corallum (theca), or it may be formed of the thickened and fused outer ends of the septa (pseudotheca). The outer ends of the septa are frequently continued beyond the wall as *costæ*. Often an outer more or less wrinkled envelope or *epitheca* occurs, which shows concentric lines of growth. Between the septa are various endothecal structures, such as cross plates or *dissepiments*, cross-bars or *synapticulæ*, or continuous floors or *tabulæ* which extend across the whole coral. In some cases the interior consists of a spongy mass, the septa being very rudimentary (*Cystiphyllum*). The septa may be smooth, or furnished with granules, or reinforced by vertical beams, which on cross section or in the calyx of the coral, look like short regular bars (*carinæ*) crossing the septum, and extend a short distance on each side (*Heliophyllum*). The upper edges of the septa in the calyx may be spinous, or smooth. A central rod or *columella* is frequently present, and

Digitized by Google

varies in form and texture. The twisting of the septa at the center may give the appearance of such a structure (pseudocolumella).

In Palæozoic corals the arrangement of the septa is often clearly seen to be in four groups (*Tetracoralla*) distributed in corresponding quadrants. This arrangement is frequently well marked by the course of the lines which on the exterior indicate the division between the septa. A main or cardinal septum is distinguishable, from which at either side branch off secondary septa in a pinnate fashion (Fig. 75, *h*). These occupy the two cardinal quadrants, and are limited by the *alar* septa on the sides of the corallum (Fig. 75, *s*). From the alar septa branch off other secondary septa in a pinnate fashion on the side away from the cardinal septum, these filling the two *counter quadrants* which are divided from each other by the counter septum, which lies directly opposite the cardinal septum (Fig. 75, *g*). The cardinal septum is frequently reduced so as to leave a marked groove or *fossula*. The secondary septa are often united to each other in such a manner that their united ends form a continuous wall around the fossula, or they may unite in groups, one on either side of the cardinal septum and one near each alar septum. The apparent grooves thus produced are the *pseudofossulæ*. This wall may sometimes close completely so as to form an inner tube, into which the septa do not extend. Tertiary septa often not reaching the center occur. In most Mezozoic and later corals the septa occur in multiples of six, and are often very numerous, most of the cycles of septa reaching the center.

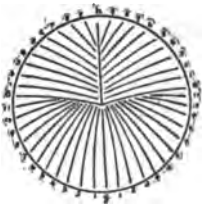


FIG. 75. Kunth's diagram of tetrameral coral. *h*, cardinal; *g*, counter; *s*, *s*, lateral or alar septa.

In compound forms the corallites may be crowded, when they are generally prismatic in form, or they may be far apart, remaining either entirely dissociated at the upper surfaces, or being connected by a dense or coarse calcareous tissue — the *cœnenchyma*. Sometimes the corallites are connected merely by their strongly developed costæ. In a few cases they become confluent by incomplete division, and present the character of winding grooves with the septa pointing to the center of the groove. When the septa are absent tabulæ are generally well developed (*Favosites*) which in some forms may be funnel-shaped (*Syringopora*). The walls of such corallites are frequently pierced by a more or less

Digitized by Google

regular series of round holes or *mural pores*. A series of small shelves or *squamæ* are generally found on the inside of the wall near these mural pores. In form the compound coral mass may be a hemispheric or spherical "head," a plate-like expansion, or variously branching with cylindrical branches.

LITERATURE.

1851. Milne-Edwards, H., et Haime, J. Monographie des Polypiers Fossiles des Terraines Paléozoiques. Arch. du Museum, Paris, Vol. V. (describe many American species).

1874. Nicholson, H. A. Palæontology of the Province of Ontario, Toronto.

1876. Rominger, C. Fossil Corals. Geol. Surv. Michigan, Vol. III., pt. II., pls. 1–55.

1843–87. Hall, James. Palæontology of New York. Vols. 1, 2, 3, 6, and Illustrations of Devonian Fossils.

1879. Nicholson, H. A. Tabulate Corals of the Palæozoic Period. Blackwood & Sons.

1882. Hall, James. Fossil Corals of the Niagara and Upper Helderberg Groups. 12th Report Indiana Geol. Surv.

1885. Davis. Kentucky Fossil Corals. Geol. Surv. Kentucky.

1900. Vaughan, T. Wayland. The Eocene and Lower Oligocene Coral Faunas of the United States. Mon. U. S. Geol. Surv., 39.

1898 to date. Green, G. K. Contributions to Indiana Palæontology.

1899–01. Lambe, Lawrence M. A Revision of the Genera and Species of Canadian Palæozoic Corals. Geol. Surv. Canada, Contr. to Canad. Pal., Vol. 4.

KEY TO THE GENERA.

A. Coral simple..... *.
  * Surface covered by a wrinkled epitheca which extends to the edge of the calyx.. †.
    † Coral conical, cylindrical, or compressed conical not composed of invaginated cups or funnels .... *a*.
      a. Septa well developed, the longer reaching to center..... *aa*.
        aa. Central columella well developed, not formed by the septa..... 1.
          1. Coral compressed, columella spongy, septa numerous in multiples of six, earlier ones much larger than later ones. LIII. *Flabellum*.
          1. Coral conical columella projecting and solid..... 11.
            11. Columella compressed..... XXVII. *Lophophyllum*.
            11. Columella round..... Cyathaxonia.
        aa. Columella absent, pseudocolumella sometimes formed by twisting of septa ..... 2.
          2. Coral conical (cylindrical), the tetrameral arrangement of the septa visible in the calyx or in the external septal grooves. ..... ‡.

Digitized by Google

‡ Epitheca normally wanting in basal portion.
XXVI. *Duncanella.*

‡ Epitheca complete (except when denuded)..... 22.

22. Septa radial in calyx, rarely uniting or twisted at the center, fossula well developed ..... *x.*

x. Septa smooth, tabulæ well developed.
(Compare *Streptelasma.*) II. *Zaphrentis.*

x. Septa carinate.
40. (*Heliophyllum corniculum*).

22. Septa radial, twisted or united in the center, fossula rarely developed.
(Compare *Zaphrentis.*) I. *Streptelasma.*

22. Septa radial, not twisted at the center. Fossula absent *xx.*

xx. Septa smooth ..... XIV. *Cyathophyllum.*

xx. Septa carinated..... XVI. *Heliophyllum.*

22. Septa arranged in a bilateral manner..... *xxx.*

xxx. Strong fossula to which the adjoining septa converge..... IV. *Aulacophyllum.*

xxx. Fossula occupied by large cardinal septum, septa uniting into four groups.
1. *Streptelasma profundum.*

2. Coral cylindrical, the tetrameral arrangement obscure... 33.

33. Fossula and tabulæ well developed ..... *xxxx.*

xxxx. Septa twisted at the center and with the tabulæ elevated tent-like ..... V. *Acrophyllum.*

xxxx. Septa not twisted or faintly so, sometimes not quite reaching center..... II. *Zaphrentis.*

33. Fossula weak or absent, tabulæ in central portion only. *xxxxx.*

xxxxx. Septa carinated, fossula occasionally developed..... ..... XVI. *Heliophyllum.*

xxxxx. Septa smooth..... ..... *y.*

y. Septa reaching to center, fossula absent or partly developed and faint.
XIV. *Cyathophyllum.*

y. Septa not fully reaching center, fossula present and faint..... XV. *Campophyllum.*

a. Septa well developed, not reaching to center..... *bb.*

bb. Septa, short strong vertical ridges, tabulæ well developed.
VII. *Pycnostylus* (single branch).

bb. Septa normal, reaching part way to center..... 3.

3. Fossula present (rarely absent)..... 44.

44. Cylindrical, with numerous often sharp constrictions and well developed tabulæ..... III. *Amplexus.*

44. Cylindrical without constrictions, well developed tabulæ onto which the septa extend to within a short distance of center ..... II. *Zaphrentis.*

44. Conico-cylindrical not constricted, often abruptly bent, tabulæ in central vesicular tissue in peripheral area.
XV. *Campophyllum.*

Digitized by Google

3. Fossula absent, coral cylindrical, tabulæ well developed.
20. *Blothrophyllum promissum.*

a. Septa faint or absent, interior cystose..... X. *Cystiphyllum.*

† Coral conical or cylindrical, composed of a series of invaginated cups or funnels ..... *b.*

b. Septa well developed, interior not cystose ..... *cc.*

cc. Cylindrical, of invaginated cups, tabulæ well developed, center of calyx smooth. Fossula present or absent.
VI. *Blothrophyllum.*

cc. Cylindrical or top-shaped, consisting of invaginated funnels, septa low, reaching center ..... 4.

4. Septa twisted in center into pseudo-columella.
IX. *Ptychophyllum.*

4. Septa often weak, not twisted, no pseudo-columella.
VIII. *Chonophyllum.*

b. Septa faint or absent, interior wholly composed of cystose tissue arranged in a series of funnel-shaped layers. (Compare Chonophyllum where septa may be weak.)..... X. *Cystiphyllum.*

† Coral disk-shaped, with flat or slightly convex base covered by a wrinkled epitheca ..... *c.*

c. Septa carinated or crenulate, the larger ones reaching the depressed center, no fossula..... XI. *Palæocyclus.*

c. Septa smooth, fossula present ..... *dd.*

dd. Disk shaped, one fossula ..... XII. *Microcyclus.*

dd. Cushion or top-shaped, septa uniting into four groups, giving the appearance of two lateral fossulæ besides the cardinal one.
XIII. *Hadrophyllum.*

† Coral with one side flat, and the other arched; operculated and with the septa in low ridges..... XXIX. *Calceola.*

* Wrinkled epitheca on lower part only, or rudimentary ..... *d.*

d. Structure of coral porous..... LIX. *Balanophyllia.*

d. Structure solid, center with spongy columella... XLIX. *Parasmylia.*

* Surface free from epitheca..... ††.

†† Structure minutely porous ..... *e.*

e. Compressed often with lateral wings..... LXI. *Endopachus.*

e. Conical, pointed at base, free..... LX. *Eupsammia.*

e. Conical with broad base of fixation, septa more or less united near center..... LIX. *Balanophyllia.*

†† Structure not porous..... *f.*

f. With basal scar of attachment, conical, septa granular, columella spongy..... XLIX. *Parasmylia.*

f. Without scar of attachment, strong costæ, and alternate septa uniting.

ee. Form conical ..... LVI. *Turbinolia.*

ee. Form wedge-shaped ..... LIV. *Platytrochus.*

ee. Form disk-shaped ..... LV. *Discotrochus.*

B. Corals compound, of loosely branching cylindrical stems each with a terminal opening ..... **.

** Septa fully developed ..... †††.

††† Central columella present ..... *g.*

g. Epitheca present, columella rudimentary or wanting.
LI. *Cladophyllia.*

Digitized by Google

g. Epitheca wanting, columella papillose..... ..... L. *Pleurocora.*

††† Columella absent..... ..... *h.*

h. An inner wall present ..... *ff.*

ff. Wall often incomplete, septa carinated.
XXV. *Craspedophyllum.*

ff. Wall complete, septa not carinated..... ..... 4.

4. Inner tube small, stems uniting by epithecal prolongations.
XXII. *Eridophyllum.*

4. Inner tube rather large, stems without epithecal prolongations.
XXIV. *Diplophyllum.*

h. Inner wall wanting..... *gg.*

gg. With epithecal proliferations, septa extending to near center.
XXIII. *Synaptophyllum.*

gg. Without epithecal proliferations, septa in form of short vertical ridges..... VII. *Pycnostylus.*

gg. Without epithecal proliferations, septa well developed.
XLIX. *Cladophyllia.*

** Septa absent or represented by spines or faint ridges..... ††††.

†††† Encrusting or attached by whole under side..... *i.*

i. Pipe-like, buds regular, single or double from near end of parent colony. ..... XXX. *Aulopora.*

i. Cylindrical, irregular branching, on crinoid stems.
XXXIII. *Monilopora.*

†††† Free or only basally attached..... *k.*

k. Branches in numerous parallel bundles of thin cylindrical tubes *hh.*

hh. Branches distinct but united by hollow cross tubes at intervals. Interior with funnel-shaped tabulæ. XXXIV. *Syringopora.*

hh. Tubes united by their sides, forming a chain work. Septa sometimes quite strong..... XLIV. *Halysites.*

k. Branches thin, regular or irregular, but not in parallel bundles..... *ii.*

ii. Branches in verticils, remote tabulæ and occasional mural pores.
XXXI. *Romingeria.*

ii. Branching by bifurcating, dendroid or irregular; wall reinforced by coarse cysts..... XXXII. *Ceratopora.*

ii. Branching dendroid or irregular, wall dense, under high power appears reticulate..... XXXIII. *Monilopora.*

k. Branches coarse, commonly irregular; interior coarsely cystose.
28. *Cystiphyllum aggregatum.*

C. Coral compound forming heads, expansions or branching stems of numerous contiguous corallites..... ***.

*** Heads of cylindrical tubes ..... 5†.

5† Tubes without septa or with septal ridges or spines..... *l.*

l. Tubes united by porous cross branches..... XXXIV. *Syringopora.*

l. Tubes united by vesicular cœnenchyma .... XLV. *Lyellia.*

l. Tubes united by their sides and forming chains..... XLIV. *Halysites.*

l. Tubes united by their own expansions at intervals.
XXXVIII. *Chonostegites.*

5† Tubes with well developed septa..... *m.*

m. Tubes united by epithecal proliferations..... *kk.*

kk. Tubes with inner wall ..... XXII. *Eridophyllum.*

kk. Tubes without inner wall .... XXIII. *Synaptophyllum.*

Digitized by Google

m. Tubes not united by proliferations, sometimes angular ..... *ll*.

ll. Tubes with inner wall complete, septa smooth.

XXIV. *Diphyphyllum*.

ll. Tubes with inner wall often incomplete, septa carinated.

XXV. *Craspedophyllum*.

*** Heads, expansions or branching stems of prismatic tubes closely crowded. 6†.

6†. Corallites with well-developed septa..... ..... *n*.

n. With well-marked styliform pseudo-columella.

XXVIII. *Lithostrotion*.

n. Without columella..... ..... *mm*.

mm. Septa carinated .... 5.

5. Head of numerous, comparatively small prismatic corallites.

XVII. *Acervularia*.

5. Head of a few large corallites..... ..... 55.

55. Corallites separated by definite walls.

38. *Heliophyllum confluens*.

55. Corallites confluent, not separated by definite walls.

XVIII. *Phillipsastræa*.

mm. Septa smooth..... ..... 6.

6. Corallites prismatic with expanding calices, 12 strong septa uniting in adjoining calices. Mural pores regular.

XXXIX. *Thecia*.

6. Corallites slender prisms, 12 septa, numerous tabulæ, no mural pores..... XXI. *Columnaria*.

6. Corallites minute, 4 primary septa .....XLVII. *Tetradium*.

6. Corallites prismatic, septa of 2 kinds, the longer extending to the center, no tabulæ .....LII. *Septastræa*.

6. Corallites with central part of calyx elevated above peripheral part..... XIX. *Pachyphyllum*.

6† Corallites with septa absent, or represented by low ridges or rows of spines..... *o*.

o. Corallites regular prisms, with numerous tabulæ ..... *nn*.

nn. Septa in form of low ridges, with costæ; no mural pores.

XXI. *Columnaria*.

nn. Septa represented by spines or absent, mural pores in definite rows ..... XXXV. *Favosites*.

nn. Septa represented by faint ridges; tabulæ convex upward; mural pores irregularly scattered..... XXXVII. *Michelinia*.

nn. Tubes opening obliquely, openings crescentic on one side, mural pores large, scattered..... XXXIX. *Alveolites*.

o. Corallites prismatic, of varying size, tabulæ few ..... *oo*.

oo. Small hemispheric heads with basal epitheca. Mural pores irregularly scattered ..... XXXVI. *Pleurodictyum*.

o. Corallites contracting at regular intervals. Tabulæ convex upward. Septa rows of spinules..... XXXVIII. *Chonostegites*.

o. Corallites thick-walled, elongate conical, opening obliquely, mural pores present, tabulæ few. Commonly branching stems.

XLI. *Cladopora*.

*** Heads of superimposed strata or layers which are divided into depressed or elevated pentagonal areas, with septal ridges extending over them. Basal epithecæ generally preserved ..... XX. *Strombodes*.

Digitized by Google

*** Heads with larger round corallites scattered among smaller angular, often minute ones. Tabulæ numerous..... 7†.
7† Septa absent; mural pores present ..... XXXV. *Favosites.*
7† Septa present in large corallites, 12 in number; no mural pores..... *p.*
p. Septa 12 infoldings of wall, short ..... XLVI. *Heliolites.*
p. Septa well developed, spinulose, smaller corallites imperfect, vesiculose in tissue..... ..... XLVII. *Plasmopora.*
D. Corals compound, forming branching stems or expansions with numerous calices scattered over the surfaces..... ****
**** Cœnenchyma separating calices ..... 8†.
8† Calices regular, septate ..... *q.*
q. Columella papillose, cœnenchyma dense ..... 7.
7. Branches cylindrical, calices spirally arranged. LVII. *Oculina.*
7. Branches irregular, often flattened and expanded. Calices scattered..... LVIII. *Astrohelia.*
**** Branching; cœnenchyma absent..... 9†.
9† Calices distinct, with septal striæ surrounding the orifice.
r. Thick-walled with circular openings, distant superficially. XLIII. *Trachypora.*
r. Thick-walled, circular orifices in polygonally depressed calices. XLII. *Striatopora.*
9† Corallites without septal striæ .... *s.*
s. Corallites thin-walled, openings oblique, crowded, generally curved on one side ..... XL. *Alveolites.*
s. Corallites thick-walled, orifices irregular, distant.... XLI. *Cladopora.*
s. Corallites opening regularly with polygonal or rounded crowded apertures. Mural pores in regular rows, tabulæ numerous. XXXV. *Favosites.*

Tetrameral Corals.

I. Streptelasma Hall.

Simple conical corals, generally curved, with a funnel-shaped calyx, which is generally deep and furnished with numerous septa, the longer of which are in some species twisted at the center. Fossula present in later types. Tetrameral arrangement of septa shown by their external ends. Epitheca thin. Interior marked by tabulæ. Ord.–Dev.

1. **S. profundum** (Owen). (Fig. 76, *a–b.*) Lower Ordovicic.

Deep calyx and few septa, the septa not twisted at the center, and strongly crenulated in their margins. Primary septa strong and three pseudo-fossulæ well developed, formed by union of ends of septa next to cardinal and alar septa. Cardinal one double and divided by cardinal septum.

In beds of Black River, Chazy, and doubtfully Beekmantown age, Michigan, Wisconsin, Iowa, New York, Canada, etc.

Digitized by Google

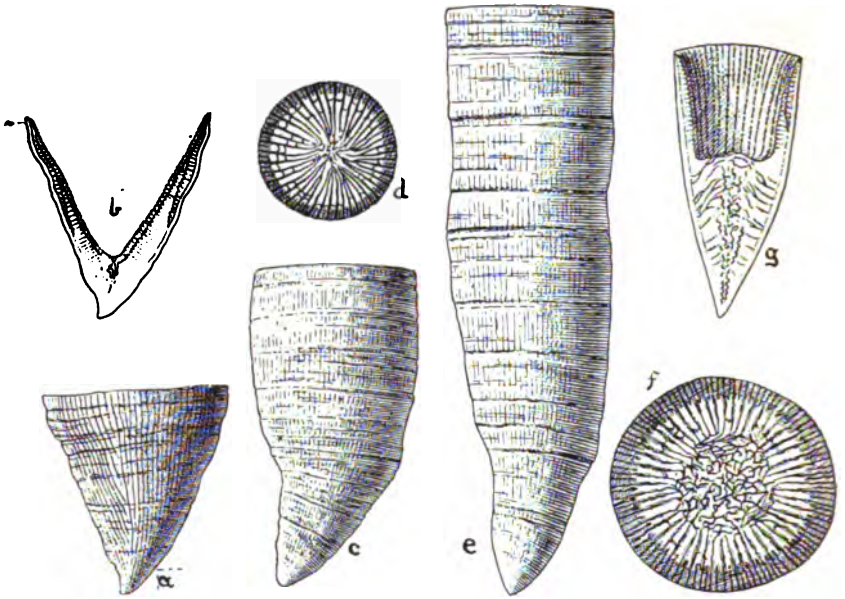


FIG. 76. *a–b, Streptelasma profundum; c–d, S. corniculum; e–f, S. rusticum; g, Enterolasma calicula* (Lambe-Contr. Pal.).

2. **S. corniculum** Hall. (Fig. 76, *c–d.*) Middle Ordovicic.

Corallum curved, calyx moderate, septa numerous, twisted at the center.

Trenton and Galena limestone, New York, Canada, Iowa Minn., etc.

3. **S. rusticum** Billings. (Fig. 76, *e–f.*) Upper Ordovicic.

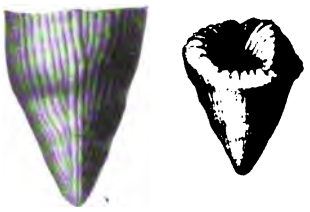


FIG. 77. *Streptelasma* (*Enterolasma*) *calicula* (N. Y. State Geol. Surv.).

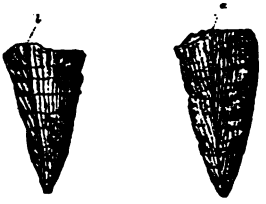


FIG. 78. *Stereolasma rectum*, (*a*) cardinal and (*b*) alar views.

Larger than preceding (2½–3½ inches), septa coarser and more strongly twisted, forming a vesicular pseudocolumella at the center.

Lorraine and Richmond beds of Minnesota, Iowa, Indiana, Ohio and Canada.

Digitized by Google

4. **S. (Enterolasma) caliculum** Hall. (Fig. 76, *g*, 77.) Middle Siluric.

Small, slender, uniformly tapering corals with moderately deep cup, and comparatively few (20–50) septa separated by twice their width, and epitheca thin, showing costal grooves. Septal ends unite into a reticulate pseudo-columella.

Niagara beds of New York, Canada, etc.

5. **S. (Stereolasma) rectum** Hall. (Fig. 78, 79.) Middle Devonic.

Generally larger and more robust than preceding, with strongly wrinkled and often irregular surface, owing to strong epitheca. Septa comparatively few, uniting at the center. A well marked fossula is present.

Hamilton group of NewYork,etc.

FIG. 79. *Stereolasma rectum*, transverse and longitudinal sections (after Simpson).

II. ZAPHRENTIS Rafinesque.

Simple, conical or turbinate corals, becoming conico-cylindrical in some large species.

Calyx deep, with well developed septa, the primary ones generally reaching to the center. Dissepiments and tabulæ occur, the latter usually well developed and bent downwards at the periphery. A deep fossula marks the abortion of the cardinal septum. Epitheca thin. Sil.–Carb.

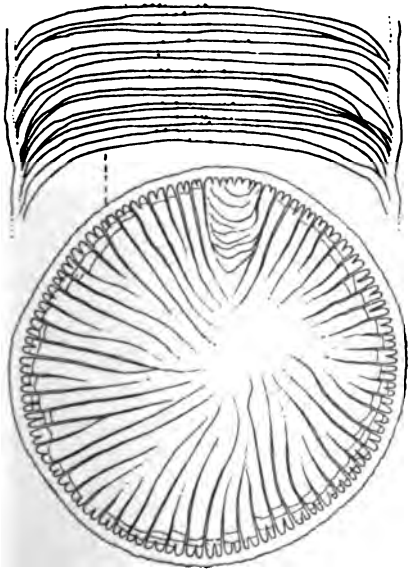


FIG. 80. *Zaphrentis gigantea*, longitudinal and transverse sections (Lambe).

6. **Z. gigantea** Lesueur. (Fig. 80.) Middle Devonic.

Generally of large size becoming cylindrical in the adult. Length sometimes 2½ feet with a diameter of three inches. Bottom of calyx often shows a tabulum, the septa not reaching the center. Fossula large and deep. Epitheca strongly wrinkled.

Digitized by Google

Found in the Onondaga limestone of New York, Canada, Michigan, Ohio. Abundant at the Falls of the Ohio.

7. **Z. prolifica** Billings. (Fig. 81.) Middle Devonic.

Conical and generally curved, expanding rapidly. Septa meet at the center of the deep calyx, where they unite more or less. Broad fossula formed by abortion of cardinal septum.

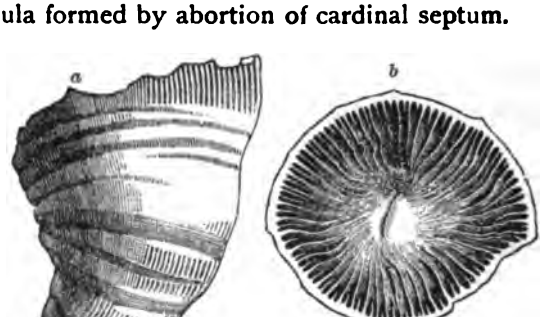


FIG. 81. *Zaphrentis prolifica*, lateral (*a*) and calicinal (*b*) views (after Billings).

Found in the Onondaga limestone of Michigan, Canada, Ohio, Kentucky, etc., and in the Hamilton group of Michigan, Canada, etc.

8. **Z. convoluta** Hall. Middle Devonic.

Conical and rapidly expanding. The septa unite before reaching the center and become more or less twisting.

In the Onondaga limestones of the Falls of the Ohio.

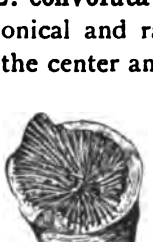


FIG. 82. *Zaphrentis simplex* (Pal. N. Y., Hall).

9. **Z. simplex** Hall. (Fig. 82.) Middle Devonic.

More cylindrical than the preceding, regularly tapering, septa scarcely reach the center.

In the Hamilton shales of New York.

10. **Z. stokesi** E. & H. Siluric.

Conical and curved with moderately deep calyx, in which the septa unite in the center and become twisted as in *Streptelasma*. A stong fossula and tabulæ are present.

In the Niagara of Canada, Michigan, Iowa, etc., and in equivalent beds of Anticosti aud Lake Temiscaming.

Digitized by Google

11. **Z. cliffordana** Edwards & Haime. Lower Carbonic.

Corallum a curved cone, with a deep calyx, the septa of which are all nearly equal in strength, becoming thinner towards the center. Fossula generally on the side of least curvature.

FIG. 84. *H. calcareforme.* Transverse section (Simpson).

FIG. 83. *Hapsiphyllum calcareforme* (Ind. Geol. Surv.).

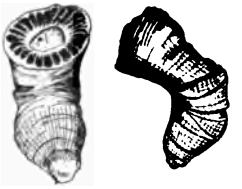


FIG. 86. *Amplexus hamiltoniæ.*

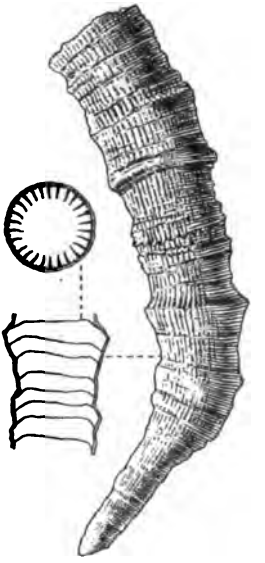


FIG. 85. *Amplexus yandelli* with transverse and longitudinal sections (Lambe Contr. Can. Pal.).

In the Kinderhook beds of Illinois, the Chester beds of Ohio, etc.

12. **Z. (Hapsiphyllum) calcareformis** Hall. (Figs. 83, 84.) Lower Carbonic.

Small, slender and uniformly tapering, sometimes curved. Fossula narrow, outlined by a compressed horseshoe-shaped wall formed of septa united at the center. Shorter septa joining the longer which in turn unite with the wall of the fossula.

In the St. Louis limestone of Spergen Hill, Lanesville, Indiana, and other localities.

13. **Z. (Hapsiphyllum) spergenensis** Worthen. Lower Carbonic.

Like the preceding, but with two rudimentary pseudofossulæ, and short epithecal spines.

Occurs with the preceding.

III. AMPLEXUS Sowerby.

Generally cylindrical or conico-cylindrical corals, with structure much like *Zaphrentis* but with the septa only reaching a short way out onto the well developed horizontal tabulæ. A strong fossula is generally present. Ord.?–Carb.

Digitized by Google

14. **A. shumardi** (E. & H.). Middle Siluric.

Subcylindrical with numerous subregular constrictions all covered by a thin epitheca. Fossula well developed.

In the Niagara group of Michigan, Iowa, Kentucky, Tennessee, etc.

15. **A. yandelli** (E. & H.). (Fig. 85.) Middle Devonic.

Irregularly cylindrical, often bent, constrictions irregular; tabulæ more or less irregular.

In the Onondaga limestone of Indiana, Kentucky, Michigan and Canada.

16. **A. hamiltoniæ** Hall. (Fig. 86.) Middle Devonic.

Small, cylindrical, often abruptly bent and constricted. Strong distant septa reach about a third to the center, and stop abruptly. Tabulæ flat.

Abundant in the Hamilton shales of New York.

IV. Aulacophyllum E. & H.

Like *Zaphrentis*, but the septa on either side of the fossula converging toward it. Ord.?–Dev.

17. **A. sulcatum** d'Orbigny. (Fig. 87.) Middle Devonic.

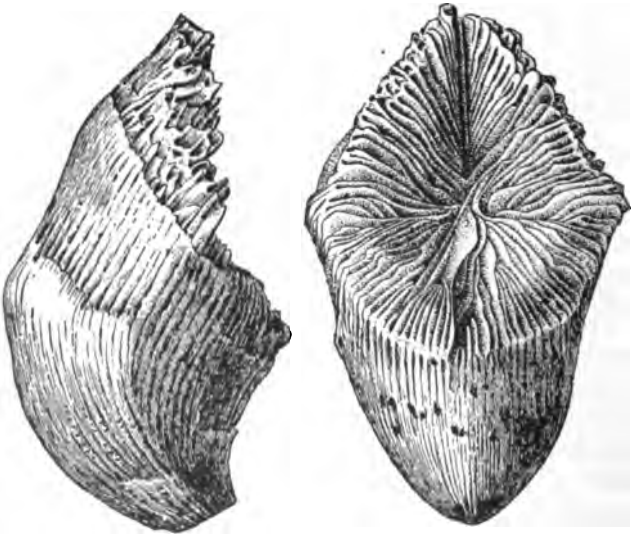


FIG. 87. *Aulacophyllum sulcatum* (Ind. Geol. Survey).

Digitized by Google

Regularly curved, with oblique calyx, most of the septa converging to either cardinal or alar septa.

Onondaga of Falls of the Ohio and other localities.

V. ACROPHYLLUM Thompson & Nichols.

Similar to *Zapherntis* but with the tabulæ elevated tent-like in the center of the calyx, the septa running out on them and twisted at the center. Dev.

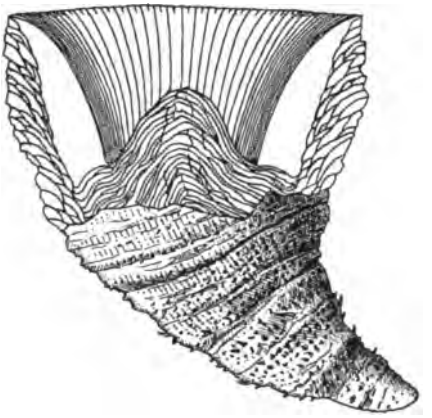


FIG. 88. *Acrophyllum oneidaense* with calyx partly sectioned (Lambe).

18. **A. oneidaense** (Billings). (Fig. 88.)
Middle Devonic.

Turbinate or subcylindrical, with periodic constrictions. Sides of calyx nearly vertical, bottom of cup nearly half the diameter of the coral. Fossula strong, extending from base of elevation to the margin of the calyx.

Onondaga limestone, Falls of Ohio, etc.

VI. BLOTHROPHYLLUM Billings.

Cylindrical corals, consisting of a series of invaginated cups which are like that of *Zaphrentis* in structure, with well-developed tabulæ, and generally a marked fossula. Projecting margins of the older cups covered by the epitheca, when not worn away. Sil.–Dev.

19. **B. decorticatum** Billings. Middle Devonic.

Large, with margins of old cups strongly projecting, generally denuded of epitheca. In the calyx a deep fossula and smooth central space are characteristic.

In the Onondaga limestones of Michigan, Canada and the Falls of the Ohio.

20. **B. promissum** Hall. (Figs. 89–90.) Middle Devonic.

Slender cylinders with margins of old cups generally subdued, the calyx with a flat central area free from septa, and no fossula.

In the Onondaga beds of the Falls of the Ohio.

Digitized by Google

VII. Pycnostylus Whiteaves.

Corallum of cylindrical tubes increasing by calicular budding of three or four branches at distant intervals. Septa in form of short vertical ridges, tabulæ well developed, horizontal. Siluric.

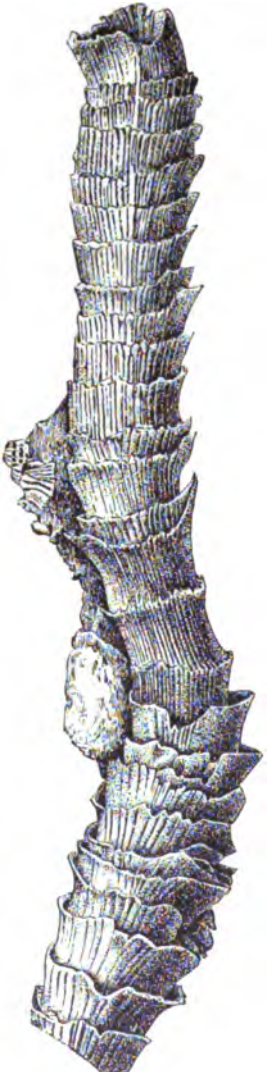


Fig. 89. *Blothrophyllum promissum* (Ind. Geol. Survey).

Fig. 90. *Blothrophyllum promissum.* Sectioned (Ind. Geol. Survey).

Fig. 91. *Pycnostylus guelphensis* with 2 buds sectioned (Lambe).

Fig. 92. *Chonophyllum niagarense* (N. Y. Geol. Survey).

Digitized by Google

21. **P. guelphensis** Whiteaves. (Fig. 91.) Siluric.

Long slender corals from 3 to 7 mm. in diameter. Epitheca with transverse constrictions and reëlevations at irregular intervals, but no longitudinal ribs.

Common in the Guelph beds of Canada, Wisconsin, Ohio, etc.

VIII. Chonophyllum E. & H.

Generally top-shaped or subcylindrical corals composed of invaginated funnels. Calyx large with numerous uniform septa. Margins of old funnels not projecting. Sil.–Dev.

22. **C. niagarense** (Hall.). (Fig. 92.) Siluric.

Cylindrical in the upper portion with frequent constrictions, septa subdued, spiniform, with notched margins, extending to the center of the deep calyx.

In the Niagara formation of Western New York, Kentucky, etc.

23. **C. magnificum** (Billings). Middle Devonic.

Large, top-shaped, with a spreading basin-shaped calyx. Septa thickening outward.

In the Onondaga beds of Michigan, Indiana and the Falls of the Ohio.

IX. Ptychophyllum E. & H.

Similar to *Chonophyllum* but with the septa twisted into a pseudo-columella, at the center. Sil.–Dev.

24. **P. stokesi** E. & H. Middle Siluric.

Conical with a deep spreading calyx, furnished with low, broad septa and a large pseudo-columella. Epitheca with root-like processes.

In the Niagara beds of Drummond Island, Mich., and Louisville, Ky.

X. Cystiphyllum Lonsdale.

Simple or compound corals, varying from depressed turbinate to cylindrical or irregular growth. Entire interior of coral filled with vesiculose tissue with a cone arrangement of the vesicles. Calyx without septa or with only faint ridges as in *Chonophyllum*, from which genus it is probably derived. A strongly wrinkled epitheca is present. Sil.–Dev.

Digitized by Google

25. **C. vesiculosum** Goldfuss (= *C. americanum* E. & H.). (Fig. 93.) Devonic.

Large, cylindrical, frequently constricted, covered by a thin but strongly wrinkled epitheca. Calyx with a faint simulation of septa. Vesicular tissue coarsest near the center.

FIG. 93. *Cystiphyllum vesiculosum.*

FIG. 94. *Cystiphyllum conifollis* (Pal. N. Y.).

FIG. 95. *Cystiphyllum varians* (Pal., N. Y.).

Abundant in the Onondaga and Hamilton strata of New York, Canada and Michigan, Ohio, etc., also at the Falls of the Ohio.

26. **C. conifollis** Hall. (Fig. 94.) Devonic.

Slender, cylindrical, with periodic constrictions. Cysts arranged radially at the base of the calyx.

Common in the Hamilton group of New York, Canada, etc.

Digitized by Google

27. **C. varians** Hall. (Fig. 95.) Devonic.

Shorter and stouter than preceding, with stronger septal ridges and coarser cysts arranged cup in cup.

Hamilton group of New York, etc.

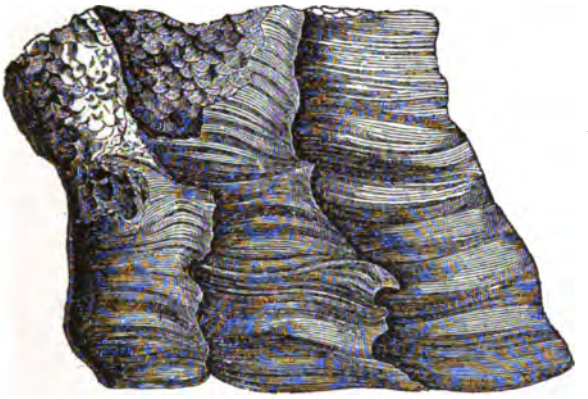


FIG. 96. *Cystiphyllum aggregatum* (after Billings).

28. **C. sulcatum** Billings. Devonic.

Short conical and curved form (zaphrentoid) with a deep cardinal fossula, and septa represented by coarse plications of the calyx floor. Cystoid structure not visible in calyx.

In the Onondaga beds of New York, Canada, Michigan and the Falls of the Ohio.

29. **C. aggregatum** Billings. (Figs. 96–97.) Devonic.

Compound, of cylindrical stems more or less closely crowded.

In the Onondaga limestone of Canada and the Hamilton of Michigan.

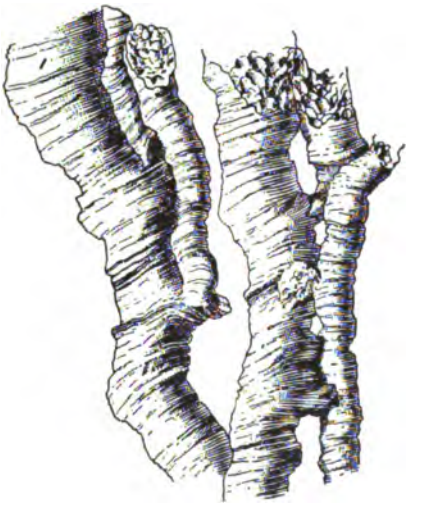


FIG. 97. *Cystiphyllum aggregatum* var. (after Lambe).

XI. PALÆOCYCLUS E. & H.

Corallum simple, disk-shaped with flat base, or depressed topshaped, the base covered

Digitized by Google

with a strong epitheca. Septa numerous, radial, in several cycles the larger ones reaching the center. Siluric.

30. **P. rotuloides** Hall. Siluric.

Center with a strong depression. About 20 thick crenulated primary septa and an equal number of secondary ones. Base with sharp costal ridges.

In the Clinton beds of New York.

XII. Microcyclus Meek & Worthen.

Disk-shaped coralla, with a flat base covered by an epitheca, with numerous radiating septa and a septal fossula. Devonic.

31. **M. discus** M. & W. (Fig. 98.) Devonic.

Fig. 98. *Microcyclus discus* (enlarged, × 2).

Fig. 99. *Hadrophyllum d'orbignyi* (enlarged × 2).

Center depressed, smooth, adjoining septa uniting half way to center, fossula well marked. Base flat and with a concentrically striate epitheca.

In the Hamilton beds of Canada and Illinois.

XIII. Hadrophyllum E. & H.

Cushion-shaped to top-shaped coralla, the base covered by an epitheca. A large cardinal fossula and two small lateral pseudo-fossulæ occur. Devonic.

32. **H. d'orbignyi** E. & H. (Fig. 99.) Devonic.

Flat cushion-shaped, the septa uniting before reaching center; pseudo-fossulæ sometimes wanting.

In the Onondaga beds of the Falls of the Ohio region.

XIV. Cyathophyllum Goldfuss.

Corallum simple in primitive species but becoming compound in more specialized types. Corallites conical, generally cylindrical in

Digitized by Google

the later stages of growth. Septa simple, without carinæ, extending to the center of the calyx where they are more or less twisted. One or more fossulæ present in some species. Tabulæ in central, cystose structure in peripheral areas. Ord.?–Carb.

33. **C. robustum** Rom. Middle Devonic.

Generally large, growth irregular, calyx deep, septa low, thin and sharp, the longer reaching the center and uniting. Fossula faint.

Hamilton group of western New York, Ontario and Michigan. Also at the falls of the Ohio.

34. **C. conatum** Hall. (Fig. 100.) Middle Devonic.

FIG. 100. *Cyathophyllum conatum* (Pal., N. Y.).

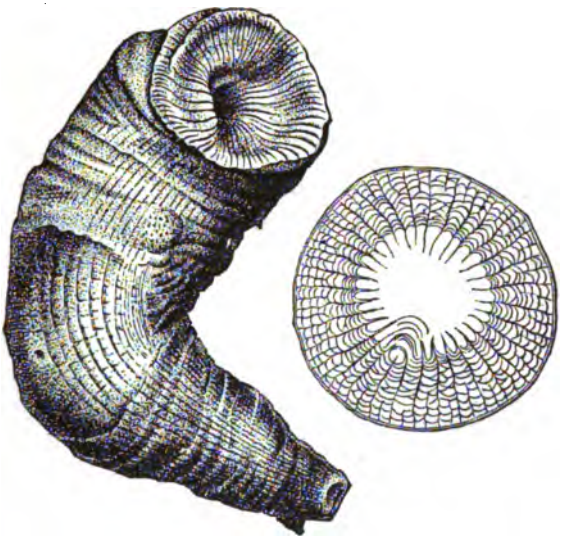


FIG. 101. *Campophyllum torquium* with cross section (Ind. Geol. Surv.).

Cylindrical, generally small, and of irregular growth. Septa strong and regular reaching the center. No fossula. Has many characters of *Blothrophyllum*.

In the Hamilton group of New York and Ontario.

35. **C. alpenense** Winch. Devonic.

Cylindrical to conico-cylindrical, rather smooth; calyx deep with steep sides marked by septa of a triangular cross-section. Tabulæ well developed in central portion.

Abundant in the Hamilton beds of Michigan.

Digitized by Google

XV. Campophyllum E. & H.

Differs from *Cyathophyllum*, in that the septa stop short some distance from the center. The central area with well developed tabulæ, the interseptal space with dissepiments. Dev.–Carb.

Fig. 102. *Heliophyllum halli* (Pal., N. Y.).

36. **C. torquium** (Owen). (Fig. 101.)
Middle Carbonic.

Cylindrical, often very long (9 inches or more) and abruptly bent. Epitheca very thin generally denuded. Calyx deep with a moderate fossula, principal septa extending one half to two third distance to center, secondary ones very short.

In the coal measures of Illinois, Iowa, Kansas, Missouri and Nebraska.

XVI. Heliophyllum Hall.

Like *Cyathophyllum*, but the septa with transverse plates or carinæ which are few and weak in young or primitive species, but numerous and strong in others. A fossula is frequently developed. Dev.

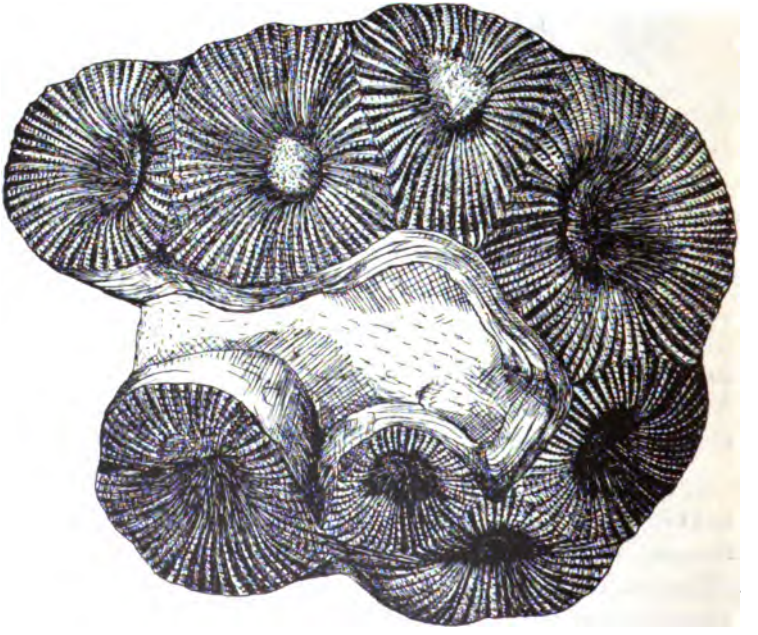


Fig. 103. *Heliophyllum confluens.*

Digitized by Google

37. **H. halli** E. & H. (Fig. 102.) Middle Devonic.

Broadly turbinate at the base or in young specimens, becoming cylindrical in old individuals, frequently with irregular constrictions showing rejuvenescence. Epitheca strongly wrinkled.

Abundant in the Hamilton group of New York, Ontario, Ohio, etc., and at the Falls of the Ohio.

38. **H. confluens** Hall. (Fig. 103.) Middle Devonic.

Likethe preceding but compound, the corrallites large, and polygonal from crowding.

In the Hamilton group of New York, Canada, Ohio, etc.

39. **H. tenuiseptatum** (Billings). Middle Devonic.

Generally small, more or less cylindrical, with numerous fine and thin septa, strongly carinated.

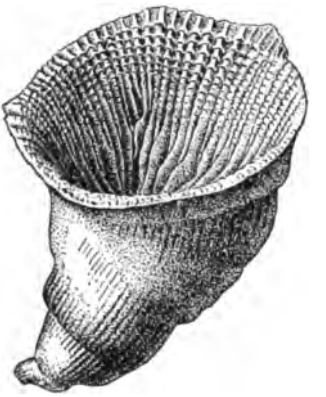


FIG. 104. *Heliophyllum corniculum* (Ind. Geol. Surv.).

Common in the Hamilton group of New York, Ontario, etc.

40. **H. corniculum** (Lesueur). (Fig. 104.) Middle Devonic.

Conical and curved at the base, general aspect like *Zaphrentis*. Calyx deep, with steeply sloping sides; broad nearly flat bottom, numerous alternating carinated septa and a well marked fossula.

Common in Onondaga limestones of New York, Ontario, Indiana, etc., and at the Falls of the Ohio.

XVII. ACERVULARIA Schweigger.

Coral heads astræiform, composed of prismatic corallites with numerous septa, the longer of which reach the center. The appearance of an inner wall is caused by crowded dissepiments at the same level. Base of colony covered with a strong peritheca. Sil.–Dev.

41. **A. rugosa** (E. & H.). (Fig. 105.) Devonic.

Corallites from 10 to 15 mm. in diameter, individuals ribbed longitudinally on the exterior and with transversely wrinkled epitheca. Larger septa meeting and sometimes twisting in the center, carinæ moderately developed.

In the Onondaga beds of Michigan, the Falls of the Ohio, etc.

Digitized by Google

42. **A. davidsoni** E. & H. (Fig. 106.) Devonic.

Centers of calices abruptly depressed, diameter about 10 mm. Septa alternating in length but equal in thickness at the margin of the calyx, carinæ abundant.

Common in strata of Hamilton age in Michigan, Iowa, etc., and

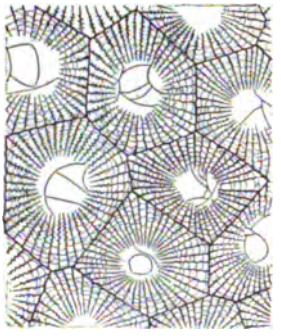


FIG. 105. *Acervularia rugosa* (after Simpson).

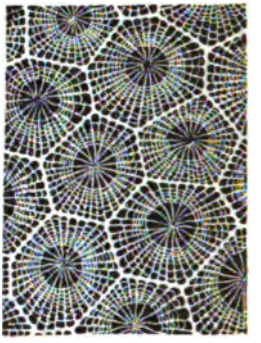


FIG. 106. *Acervularia davidsoni* (after Simpson).

also found in strata of somewhat earlier age at the Falls of the Ohio and elsewhere.

XVIII. PHILLIPSASTRÆA D'Orbigny.

Coral heads composed of large confluent corallites, similar to compound *Heliophyllum*, but without the dividing walls. Calicular surfaces flat, except at the center, where an abrupt depression, usually surrounded by an elevated rim occurs. Longer septa uniting at the center, shorter stop at the central pit. Dev.–Carb.

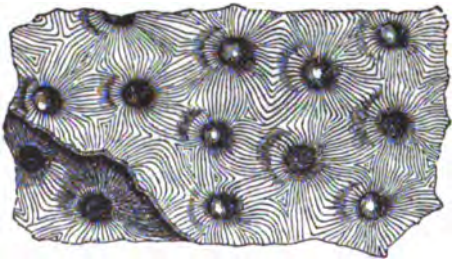


FIG. 107. *Phillipsastræa verneuilli* (after Billings).

43. **P. gigas** Owen. Devonic.

Large, the calices over 20 mm. in diameter and their outlines defined; central pit large.

In the Onondaga limestone of New York, Canada, Michigan and the Falls of the Ohio.

44. **P. verneuilli** E. & H. (Fig. 107.) Devonic.

Smaller, corallites from 10–15 mm. in diameter.

Digitized by Google

Onondaga of Canada, Michigan, etc.

XIX. Pachyphyllum E. & H.

Compound corallites bounded by polygonal walls, each with a central conical elevation, at the top of which is a crater-like pit. Septa extending over the outside of the cone as low ridges or costæ. The longer septa extend to within a short distance of the center. Dev.

45. **P. woodmani** (White). (Fig. 108.) Upper Devonic.

Growing in convex or hemispheric masses from 1 to 6 inches in diameter; crater rims strongly elevated, sometimes more than an eighth of an inch. Crater deep and variable in diameter.

In the Upper Devonic of Iowa, etc.

XX. Strombodes Schweigger.

Coral composed of superposed layers or laminæ, on the surfaces of which are polygonal depressions representing the calices with

Fig. 108. *Pachyphyllum woodmani* (N. Y. State Mus. Rep.).

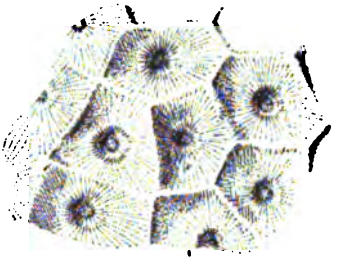


Fig. 109. *Strombodes pentagonus* (after Lambe).

the central part marked by an abrupt circular pit. Calicinal surface with radial septal ridges, which unite in the center in a papillose projection. Sil.–Dev.

46. **S. pentagonus** Goldfuss. (Fig. 109.) Siluric.

Calices shallow from 10 to 15 mm. in diameter; center with a styliform columella, septa sharp at the pit, becoming low rounded ridges at the margins.

In the Niagara beds of Michigan, the Falls of the Ohio, etc.

Digitized by Google

47. **S. striatus** Owen. Siluric.

Much larger than the preceding, the calices ranging to 40 mm. in diameter. Elevation around central pit pronounced.

Occurs with the preceding.

48. **S. mamillatus** Owen. Siluric.

Margins of calices depressed, center strongly elevated with a pronounced crater-like pit at the top from 4 to 5 mm. in diameter. Distances between centers of pits of adjoining corallites 10 to 20 mm.

In the Niagara beds of Michigan, Iowa, Kentucky, Indiana, etc.

XXI. Columnaria Goldfuss.

Heads consisting of prismatic corallites, like that of *Favosites*, but without mural pores, and with the septa either well marked or indicated by vertical ridges. Tabulæ well developed. Ord.–Dev.

49. **Columnaria halli.** (= *C. alveolata* of most authors.) Middle Ordovicic.

Septa represented by from 20 to 40 vertical ridges. Tabulæ flat, close and smooth in the centers. Tubes variable in diameter from 2 to 5 mm.; sometimes 10 mm. tubes, occur among the smaller ones.

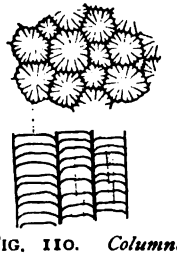


Fig. 110. *Columnaria alveolata.* Horizontal and vertical sections (Lambe).

In the Black River limestones of New York, Canada and Michigan, and in strata of the same age in Wisconsin, Illinois and Iowa, etc.

50. **C. alveolata** Goldfuss. (= *Favistella stellata* Hall.) (Fig. 110.) Upper Ordovicic to Siluric.

Tubes varying from 3 to 6 mm. in diameter. Septa from 20 to 30, alternatingly larger and smaller, the former extending to the center. Center of tabulæ marked by the septa. Common in the beds of the age of the Cincinnati group throughout the central west Also recorded by Rominger from the Niagara Group of Point Detour.

XXII. Eridophyllum E. & H.

Heads composed of loosely aggregated cylindrical corallites each surrounded by a wrinkled epitheca, from one side of which prolongations extend uniting adjoining corallites. An inner wall enclosing a narrow tabulate area is present. Sil.–Dev.

Digitized by Google

51. **E. rugosum** E. & H. (Figs. 111; 113, *a*.) Siluric.

Corallites less than 10 mm. in diameter, with prolific calicinal budding, outline cylindrical with subregular constrictions, epi-

FIG. 111. *Eridophyllum rugosum* (Ind. Geol. Survey).

thecal prolongations spiniform. Septa extending to within a short distance of the center, which is occupied by tabulæ.

Common in the Niagara beds of Indiana, Kentucky, etc.

52. **E. vernuillianum** E. & H. (Fig. 112.) Devonic.

Tubes 7 to 10 mm. in diameter, distant about their own diameter. Strong epithecal proliferations. A sharp thin inner wall enclosing a space about 2 mm. in diameter not crossed by septa.

In the Onondaga beds of northern Ohio and adjacent regions.

53. **E. colligatum** (Billings). Devonic.

Cylindrical stems expanding at regular and uniform intervals so as to unite in polygonal outlines, after which they contract and

Digitized by Google

again become round. Septa crenulate, alternating, the longer abutting against the inner wall.

FIG. 112. *Eridophyllum vernuillianum* (after Billings).

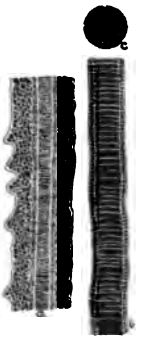


FIG. 113, *a*. *Eridophyllum rugosum*; *b*, *c*. *Synaptophyllum simcoense* (after Simpson).

In the Onondaga beds of Canada, Michigan and the Falls of the Ohio.

XXIII. SYNAPTOPHYLLUM Simpson.

Like *Eridophyllum* but without the central wall, the septa extending across the tabulate area to near the center. Proliferations from all sides of the tubes. Dev.

54. **S. simcoense** Billings. (Figs. 113*b*–115.) Devonic.

Similar in form to *Eridophyllum vernuillianum* but smaller in diameter, *i. e.*, from 4 to 6.5 mm. and distant the same amount or somewhat less. Septa from 40 to 50.

FIG. 114. *Synaptophyllum simcoense* (after Billings).

In the Onondaga limestone of New York, Canada, Michigan and the southwest.

55. **S. stramineum** Billings. (Fig. 116.) Devonic.

Tubes from 4 to 5 mm. in diameter varying from almost in contact to more than twice their width apart. Central tabulate area large, septa about 40, extending to near center.

In the Onondaga limestone associated with the preceding.

XXIV. DIPLOPHYLLUM Lonsdale.

Corolla similar to *Synaptophyllum* but without the connecting epithecal expansions. Tabulate area large. Sil.–Dev.

Digitized by Google

56. **D. cæspitosum** Hall. (Fig. 117.) Siluric.

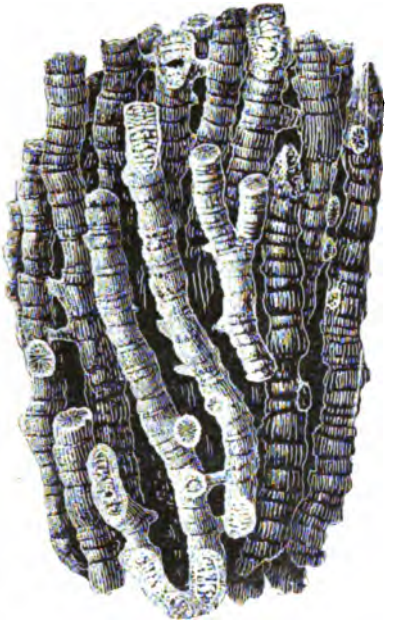


FIG. 115. *Synaptophyllum simcœnse* (Ind. Geol. Surv.).

FIG. 116. *Synaptophyllum stramineum* (Ind. Geol. Surv.).

Slender cylindrical stems with a broad central tabulate, and a narrow peripheral zone. Septa thin, reaching the center.

Digitized by Google

In the Niagara and Guelph beds of New York, Canada, Wisconsin, etc.

57. **D. panicum** Rominger. Devonic.

Large stems, about 10 mm. in diameter and multiplying by prolific calycinal gemmation. About a third of the tubes occupied by the rather vesiculose compound tabulæ, the outer zone by the carinate septa.

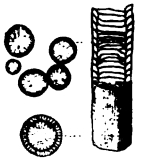


FIG. 117. *Diplophyllum cæspitosum* (after Lambe).

In the Hamilton beds of Michigan.

58. **D. arundinaceum** (Billings). Devonic.

Differs from the preceding by the narrower vesicular zone, and regular tabulæ. Septa not reaching center. Diameter of tubes 6–10 mm.

In the Onondaga limestone of New York, Canada, etc.

XXV. CRASPEDOPHYLLUM Dybowsky.

Heads of cylindrical corallites as in *Eridophyllum*, but without the epithecal prolongations and with the inner wall open on one side, rarely closed, not crossed by the carinated septa. Devonic.

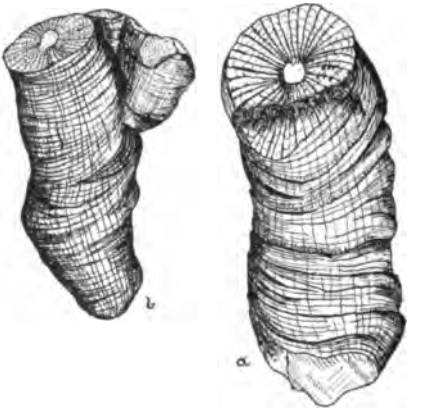


FIG. 118. *Craspedophyllum archiaci.*

59. **C. archiaci** (Billings). (Fig. 118.) Devonic.

Stems nearly or quite in contact, sometimes becoming prismatic from crowding, diameter from 10 to 20 mm. Calices deep. Septa of the first cycle joining the horseshoe-shaped inner wall.

Digitized by Google

In the Hamilton beds of New York, Canada, Michigan, etc. Also in Devonic limestones of Ohio.

60. **C. subcæspitosum** (Nicholson). Devonic.

Smaller than the preceding, of long slender stems increasing chiefly by lateral gemmation. Septa more numerous and more closely crowded than in the preceding, strongly carinated. Inner wall often closed in the adult.

Common in the Hamilton beds of New York, Canada and Michigan.

XXVI. Duncanella Nicholson.

Coral slender, resembling *Streptelasma*, with radial septa, and a strongly developed epitheca which, however, is absent at the base of the corallum, where the septa are visible. Siluric.

61. **D. borealis** Nicholson. Siluric.

Small, slender, and scarcely over half an inch in length. Costæ well developed.

In the Niagara group of Indiana and elsewhere.

XXVII. Lophophyllum E. & H.

Corallum zaphrentoid, but with a central compressed columella often continuous on one side with the cardinal septum. Carbonic.

62. **L. profundum** (E. & H.). (Fig. 119.) Carbonic.

Curved, horn-like corallum, with septa from 30 to 50 alternating in length. Columella striated. Length of average individual 30 mm., width of calyx 9 mm.

Fig. 119. *Lophophyllum profundum* (Ind. Geol. Survey).

In the coal measures of Iowa, Illinois, Kansas, Nebraska, Texas, etc.

XXVIII. Lithostrotion Lhwyd.

Heads composed of prismatic or cylindrical corallites, each enveloped by an epitheca and all by a peritheca. Central portion occupied by tabulæ which are inverted funnel-shaped, terminating in the calyx in a pseudo-columella. Septa well developed, outer area with numerous dissepiments. Carbonic.

Digitized by Google

63. **L. mamillare** E. & H. (Fig. 120.) Lower Carbonic.

Prismatic corallites, with moderately deep calices marked by the conical elevation which is carinated by the septa and terminates in a compressed pseudo-columella.

In the lower Carbonic (St. Louis) limestone of Michigan, the Mississippi Valley and Southern Appalachians generally.

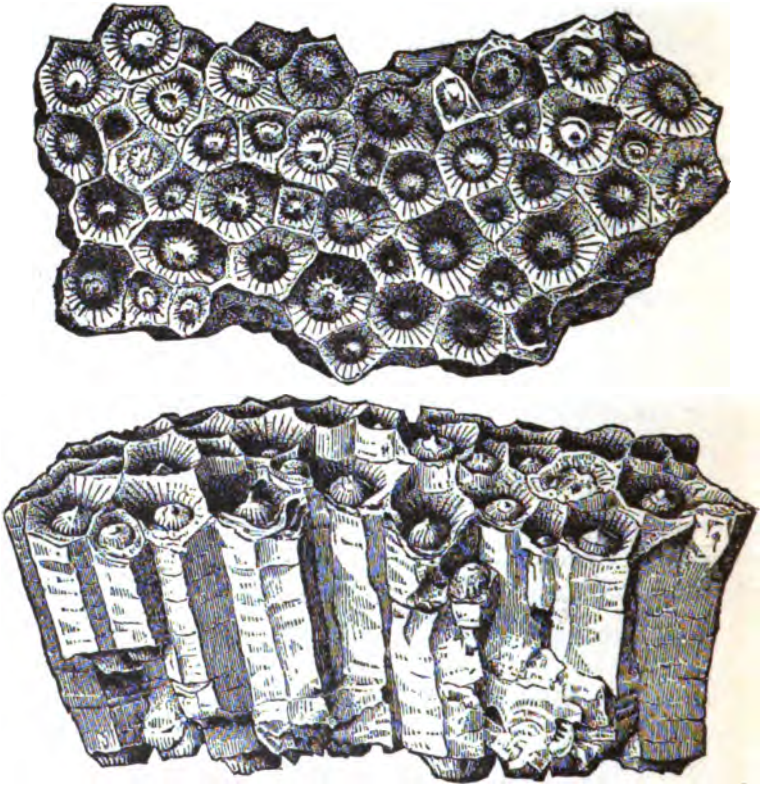


FIG. 120. *Lithostrotion mamillare* (Ind. Geol. Survey).

XXXIX. CALCEOLA Lamarck.

Coral simple with one side flattened and a deep calyx opening obliquely and furnished with an operculum; septa in the form of low ridges. Structure densely cystoid. Sil.–Carb.

64. **C. tenneseenensis** Rom. (Fig. 121.) Siluric.

Strongly curved, with a high arched operculum and interior largely occupied by vesicular tissue.

In the upper Niagara beds of Tennessee.

Digitized by Google

Tubulate Corals.

XXX. AULOPORA Goldfuss.

Compound corals attached for the greater part to shells, corals or other foreign bodies and consisting of a number of simple cornucopia-shaped to cylindrical tubes, each arising by budding from

FIG. 121. *Calceola tenneseenensis.*

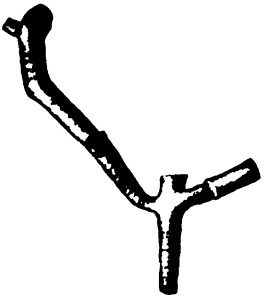


FIG. 122. *Aulopora subtenuis* enlarged (Pal., N. Y.).

below the calyx mouth of its parent, with which it remains united by a persistent pore. Tabulæ seem to be present in some species. Septa represented by vertical ridges. Ord.–Carb.

65. **A. subtenuis** Hall. (Fig. 122.) Devonic.

Slender curving tubes very gradually enlarging. Generally a single bud only. Length of tubes about 8 mm., diameter at aperture 1 mm.

Common in the Helderbergian of New York, etc.

66. **A. serpens** Goldf. (Fig. 123.) Middle Devonic.

Attached by whole under surface; calices oblique upward, buds

FIG. 123. *Aulopora serpens* on brachiopod shell.

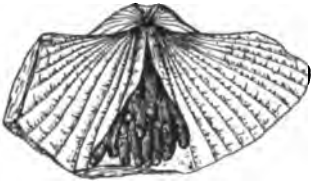


FIG. 124. *Aulopora tubæformis* on spirifer.

one or two, commonly reuniting so as to form meshwork. Commonly attached to brachiopods.

In the Hamilton shales of New York, Ontario and Michigan.

Digitized by Google

67. **A. tubæformis** Goldf. (Fig. 124.) Devonic.

Larger than preceding, with corallites crowded and occasionally uniting laterally.

In the Hamilton beds of New York, Canada, etc.

68. **A. cornuta** Bill. (Fig. 125.) Devonic.

Less crowded, mouths of corallites about twice as large as preceding.

Onondaga and Hamilton of Canada, etc.

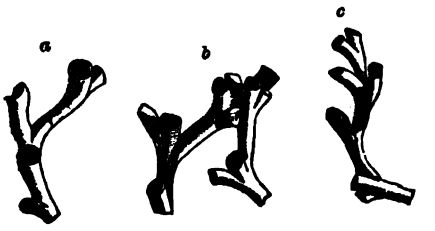


FIG. 125, *a–c*. *Aulopora cornuta* (after Billings).

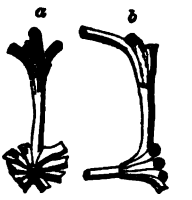


FIG. 126. *Romingeria umbellifera* (after Billings).

XXXI. ROMINGERIA Nicholson.

Auloporoid tubes with the buds given off in a verticil. Remote tabulæ, and occasional mural pores present, growth erect. Sil.–Dev.

69. **R. umbellifera** (Billings). (Fig. 126.) Devonic.

Tubes about 1 mm. in diameter, delicately annulate by growth lines. Verticils from 6 to 12 buds, remaining at first close together, then bent rather abruptly outward radially.

Onondaga limestone of New York, Canada, Michigan, etc., and Hamilton group of Michigan.

XXXII. CERATOPORA Grabau.

Coral like *Aulopora* in appearance, but tubes often much larger, and never attached except at the base. Walls thickened by the formation of coarse cysts, from the surfaces of which sharp spines arise. Central space commonly open, the individual corallites remaining connected. Epitheca generally well marked. Devonic.

70. **C. jacksoni** Grabau. (Figs. 127, 128.) Middle Devonic.

Branches budding at irregular intervals, tubes large and coarse, with longitudinal striation, marking the epitheca. Cysts coarse and irregular.

In the Hamilton group of New York.

Digitized by Google

71. **C. dichotoma** Grabau. (Fig. 129.) Middle Devonic.

Prostrate, tubes with flattened lower and carinated upper portion, and abruptly up-bent circular calices. Buds in pairs, at right angles to each other. Cysts small.

FIG. 127. *Ceratopora jacksoni.*

FIG. 128. *Ceratopora jacksoni.* Transverse and longitudinal section, × 2.

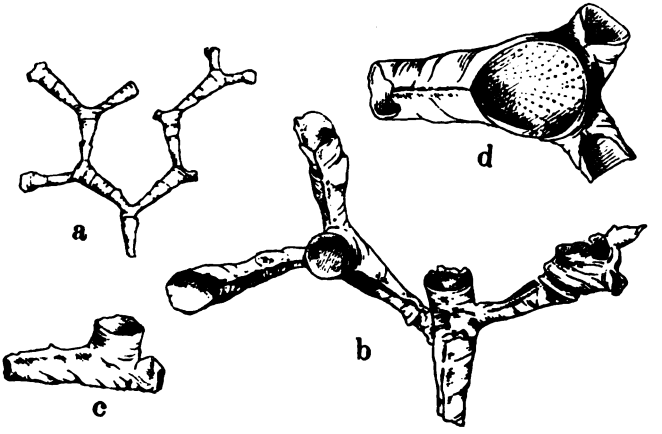


FIG. 129. *Ceratopora dichotoma.* Nat. size (*a*) and enlarged (*b–d*).

In the Hamilton beds of New York, Ontario, Michigan and the Falls of the Ohio.

72. **C. intermedia** (Nicholson). Middle Devonic.

Small cylindrical, loosely branching corallites forming a colony which probably grew erect. Epitheca smooth with only growth lines.

Digitized by Google

In the Hamilton group of New York, Ontario, Michigan, etc. Other species are abundant at the Falls of the Ohio.

XXXIII. MONILOPORA Nicholson & Etheridge.

External form similar to *Ceratopora*, but wall composed of parallel layers separated slightly, and connected by numerous

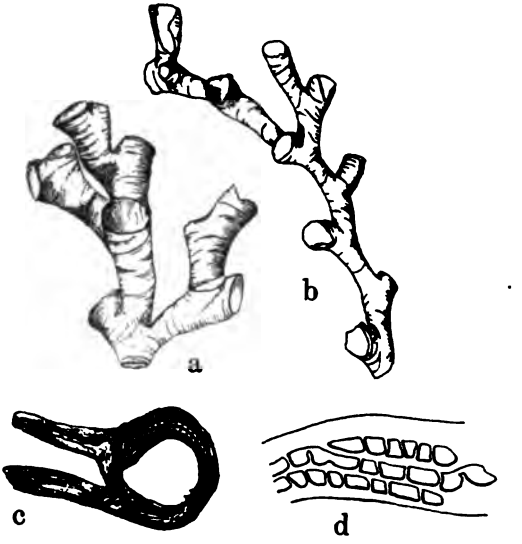


FIG. 130. *Monilopora beecheri*. *a*, *b*, nat. size; *c*, enlarged cross-section; *d*, portion of *c* still further enlarged.

transverse bars or trabeculæ, which, in section, give a regular net-like appearance. Dev.–Carb.

73. **M. antiqua** Whiteaves. Devonic.

Slender branches, surface reticulate. Free, or encrusting crinoid stems.

Hamilton beds of Canada and the Falls of the Ohio.

74. **M. beecheri** Grabau. (Fig. 130.) Lower Carbonic.

Free growing, or encrusting crinoid stems, sometimes forming a confused agglomeration. Epitheca smooth except for growth lines, tissue very dense, the lacunæ small and scattered.

Common in the Keokuk beds of the Mississippi valley.

Digitized by Google

XXXIV. SYRINGOPORA Goldfuss.

Coral consisting of numerous irregular cylindrical tubes which grow parallel but generally separated, and have at intervals transverse hollow, tubular connecting processes. Interior filled with funnel shaped tabulæ. Young as in *Aulopora*. Septa represented by spines. Sil.–Carb.

FIG. 131. *Syringopora retiformis* (after Lambe).

75. **S. verticillata** Goldfuss. Siluric.

Tubes separated by from one to two or more times their diameter (2 to 3 mm.) connected at distant intervals by transverse tubes of which 2 or 3 are given off at the same plane.

Niagara group of Canada, Michigan, etc.

76. **S. retiformis** Billings. (Fig. 131.) Siluric.

Tubes a millimeter or somewhat less in diameter, irregularly bending or geniculate, joining where in contact but not by tubes.

In the Niagara beds of New York, Canada, Kentucky, etc.

77. **S. tubiporoides** Y. & S. Devonic.

Tubes not parallel, about 3 mm. in diameter and separated by greater distances.

Onondaga limestone of Kentucky, etc.

78. **S. maclurei** Billings. (Fig. 132.) Devonic.

Tubes about 25 mm. in diameter, more regular than preceding, but coming closer together at more or less regular intervals.

FIG. 132. *Syringopora maclurei.*

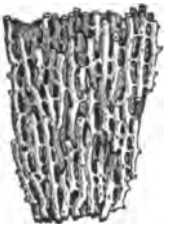


FIG. 133. *Syringopora hisingeri.* (After Billings.)

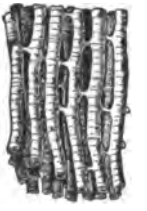


FIG. 134. *Syringopora perelegans.*

In the Onondaga limestone of New York, Canada, Michigan, etc.

79. **S. hisingeri** Billings. (Fig. 133.) Devonic.

Corallites are slender tubes of less than 1 mm. diameter, separated by their own width or a little less or more. Frequent connecting tubes occur.

Digitized by Google

In the Onondaga limestone of Canada, Michigan, Ohio, New York, Indiana, Kentucky, etc.

80. **S. tabulata** E. & H. Devonic.

FIG. 135. *Syringopora perelegans* (Ind. Geol. Survey).

Corallites slender as in the preceding, but closer together and parallel. Connecting tubes at uniform levels, giving the appearance of horizontal floors connecting the corallites.

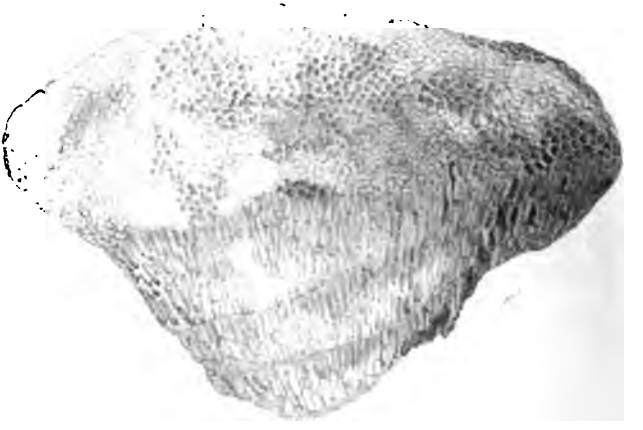


FIG. 136*a*. *Favosites venustus.*

In the Onondaga limestone of the Falls of the Ohio and elsewhere.

Digitized by Google

81. **S. perelegans** Billings. (Figs. 134–135.) Devonic.

Between *S. maclurei* and *S. hisingeri*. Associated with the preceding species.

XXXV FAVOSITE Lamarack.

Corallum massive, more rarely branching, commonly forming heads which may be a foot or more in diameter. Corallites prismatic, thin, in contact but not amalgamated by their walls, which are perforated by equidistant mural pores in one or more rows. Septa rudimentary or obsolete. Numerous more or less regular tabulæ divide the intrathecal space. Peritheca present on the under side of the colony, and usually strongly wrinkled. Ord. Carb.

FIG. 136. *Favosites venustus* enlarged sections (N. Y. Geol. Survey).

82. **F. venustus** (Hall). (= *F. hisingeri* E. & H. ?) (Fig. 135–136.) Siluric.

Heads hemispheric or spheroidal, up to 2 or 3 feet in diameter, with twelve ascending septal spines, generally visible in section.

In the Niagara group (Lockport beds) of New York, Ontario, Michigan, Cumberland, Md., Ohio and Kentucky.

83. **F. favosus** (Goldfuss). (Fig. 137.) Siluric.

Tubes large — up to 6 mm. in diameter with the inside marked

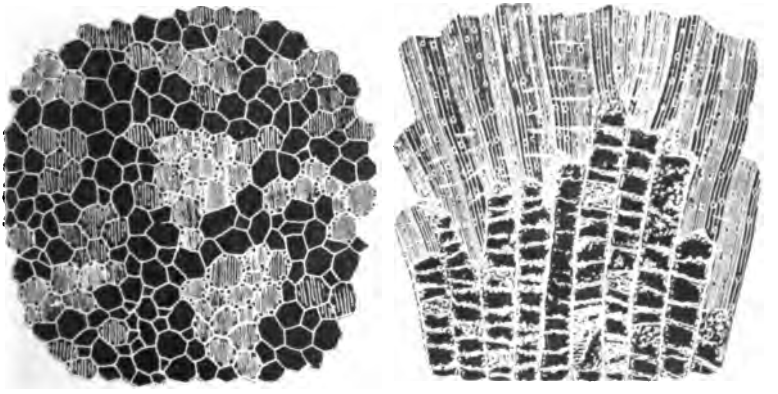


FIG. 137. *Favosites favosus* (Ind. Geol. Survey).

Digitized by Google

by twelve longitudinal furrows and by granulations. Tabulæ granulose, with their margins deflected into 12 (±) pits or notches corresponding to the longitudinal furrows, marginal pores commonly in more than two rows.

In the Niagara group of New York, Ontario, Michigan, Wisconsin, Iowa, and the Falls of the Ohio region.

84. **F. niagarensis** Hall. Siluric.

Tubes much smaller than in the preceding species (about 1.5 mm. in diameter), tabulæ rarely notched at margin; mural pores scattered near the angles of the tubes. Inner surface of tubes delicately spinulose.

In the Niagara group of New York, Ontario, Michigan, Iowa and Kentucky.

85. **F. helderbergiæ** Hall. (Fig. 138.) Lower Devonic.

Heads lenticular or hemispherical, often large, and with the base covered by a strongly wrinkled epitheca. Calices about 1.5 mm. in diameter with strong longitudinal ridges. Mural pores in one or two rows, with elevated rim. Tabulæ close.

In the Lower Helderberg beds of New York and at Cumberland, Md.

86. **F. winchelli** Rom. Devonic.

Tubes much as in *F. favosus*, but with the marginal notching rare. Not infrequently the whole rim of the septum is turned down. Interior of tube with twelve well-marked longitudinal furrows, without squamæ.

FIG. 138. *Favosites helderbergiæ* (reduced) with a group of corallites enlarged (Pal. N. Y.).

Digitized by Google

In the Onondaga limestone of New York, Canada, Michigan and the Falls of the Ohio. Also in the Hamilton group of Michigan.

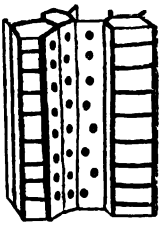


FIG. 139. *Favosites basalticus* (enlarged).

87. **F. basalticus** Goldfuss. (Fig. 139.) Devonic.

Tubes of medium size, sometimes unequal, tabulæ complete, not very close together, the squamæ often not preserved. Generally only a single line of mural pores on each wall.

In the Onondaga limestone of New York, Canada and Northern Ohio.

88. **F. tuberosus** Rominger. Devonic.

Columns of medium size (2–3 mm.), from two to three rows of mural pores on each face, and two rows of stout horizontal squamæ on inside of each face; the squamæ of adjoining rows alternating and often interlocking. Pores surrounded by small pits. Opercula frequent and concave.

In the Onondaga limestones of western New York, Canada, Michigan and the Falls of the Ohio.

89. **F. epidermatus** Rominger. Devonic.

Differs from *F. tuberosus* in irregular arrangement of squamæ and in elevated ring around the small distant pores in rarely more than two rows. Interior of tubes with twelve longitudinal furrows which are commonly visible in reverse on the outside of solid columns. The squamæ are on the spaces between the grooves and the tabulæ are complete.

Common in the Onondaga limestone of Western New York, Canada, Michigan, Indiana and Kentucky.

90. **F. emmonsi** Rominger. Devonic.

Tubes from 1 to 1½ mm. in diameter. Tabulæ for the most part very irregular, closely crowded and compound from union with squamæ; pores large, irregular, in from 1 to 3 rows and often crowded. Differs from *F. epidermatus* in the crowded incomplete tabulæ and in the large crowded pores.

In the Onondaga limestone of New York, Canada, Michigan, Ohio, Kentucky, etc.

91. **F. turbinatus** Billings. Devonic.

Form turban-like, often simulating Cyathophylloid corals, *i. e.*, cup-like; generally curved in the basal portions and not infrequently looking like the mold of large pelecypod shell. Coral-

Digitized by Google

lites curving outward, with their mouths nearly at right angles to the main axis of the coral, from 1 to 2 mm. or more in diameter, closed in perfect specimens by concentrically striated opercula. Pores generally in single rows; tabulæ complete averaging 1.5 mm. apart, squamæ generally not prominent.

In the Onondaga of western New York, Canada, Michigan, Ohio and at the Falls of the Ohio, and in the Hamilton of Canada and Michigan.

92. **F. hamiltoniæ** Hall. (Syn. *F. billingsi* Rom.) (Fig. 140.) Devonic.

Corals in form of hemispheric heads with the base covered by a wrinkled peritheca. Adult corallites up to 2.5 mm. in diameter, generally surrounded by smaller immature ones. Mural pores in two rows, frequently obscure, tabulæ perfect, sometimes crowded, more generally from 2 to 4 mm. apart, not infrequently with marginal notches. Easily recognized by its distant perfect tabulæ.

FIG. 140. *Favosites hamiltoniæ.*

Abundant in the Hamilton groups of western New York, Canada, etc.

93. **F. alpenensis** Winchell. Devonic.

Differs from *F. hamiltoniæ* in its manner of growth, which results in the formation of rounded or tuberose masses, with generally only a small space for attachment; in the somewhat smaller corallites, which are rounded tubes on the interior owing to the thickening of the walls, and in the more crowded tabulæ.

Very common in the Hamilton (Traverse) group of Michigan. Also in northwestern Canada (Manitoba, etc.). At Alpena a variety forms large heads in the coral reefs.

94. **F. canadensis** (Billings). (Fig. 141.) Devonic.

Generally a more or less flat or undulating expansion, sometimes digitate. Circular tubes, about 1 mm. in diameter, are scattered subregularly between small angular ones, of about one third their size.

Simple tabulæ in the smaller, and tabulæ complicated by squamæ in the larger ones. Opercula often present.

In the Onondaga limestone of New York, Canada, Michigan, Indiana and Kentucky.

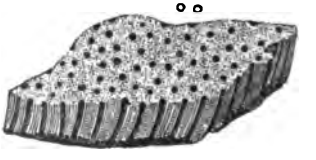


FIG. 141. *Favosites canadensis* (after Billings).

Digitized by Google

(The ramose or digitate varieties lead to *F. radiciformis* Rom.)

95. **F. placenta** Rominger. Devonic.

Grows in broad, generally thin expansions of an undulating character, the base covered by a wrinkled peritheca. Calices less than a millimeter in diameter with clusters of smaller ones scattered about. In some specimens (especially young ones), the larger tubes are circular and scattered about separately thus forming transition types from *F. canadensis*. Tabulæ of smaller tubes simple, of larger, complicated with squamæ. Pores uniserial.

Abundant in the Hamilton group of Canada and Michigan — also in the same formation in western New York.

96. **F. digitatus** Rominger. Devonic.

Irregular finger-like stems, calices polygonal from one to one and a half millimeters in diameter. Well developed transverse squamæ.

Abundant in the Hamilton beds of Canada, Michigan and other regions.

97. **F. clausus** Rom. Devonic.

Like the preceding, but with large round calices and small angular ones as in *F. canadensis*. The coarse thick branches of this general type are *F. radiciformis* Rom.

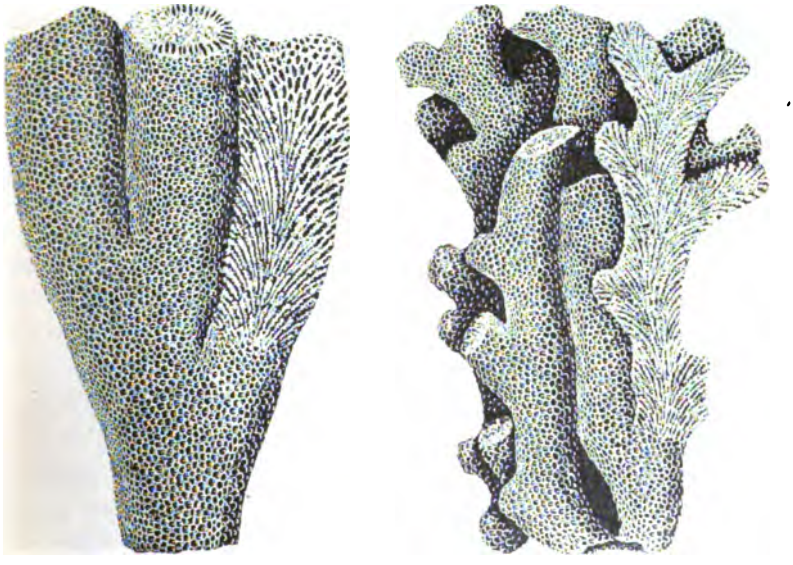


FIG. 142. *Favosites limitaris* (Ind. Geol. Surv.).

Digitized by Google

Common in the Onondaga and Hamilton beds of New York. Canada, Michigan, and the Falls of the Ohio region.

98. **F. limitaris** Rom. (Fig. 142.) Devonic.

Cylindrical, commonly branching stems 5 to 15 mm. in diameter. Calices circular, opening at nearly right angles to the axis of the branch. Walls thick, the division lines between the corallites shown only in certain states of preservation.

Common in the Onondaga limestones of the Falls of the Ohio. Also in the Onondaga and Hamilton of New York, Canada, Michigan, etc.

XXXVI. Pleurodictyum Goldfuss.

Corallum depressed, discoidal, lower surface covered by a concentrically wrinkled peritheca. Corallites small, prismatic, funnel-shaped; septa faint or obsolete, a scanty development of tabulæ occurring; mural pores irregularly distributed. Young cells as in *Aulopora*. Devonic.

99. **P. stylopora** (Eaton). (Fig. 143.) Devonic.

Heads from 1 to 2 inches in diameter, septa faint, forming a crenulation on the calyx margin; tabulæ moderately numerous. Common in the Hamilton beds of New York and Michigan.

Fig. 143. *Pleurodictyum stylopora.*

XXXVII. Michelinia De Koninck.

Convex or hemispheric heads consisting of prismatic corallites and basally covered with a wrinkled peritheca. Septa represented by longitudinal ridges. Tabulæ numerous, crowded and convex upward, often incomplete and uniting. Mural pores numerous, irregularly scattered. Differs from *Favosites* in the greater diameter of the corallites, in the crowded arched tabulæ and in the numerous irregularly scattered mural pores. Dev.–Carb.

100. **M. convexa** (d'Orbigny). (Fig. 144.) Devonic.

Calices 8 to 10 mm. in diameter. Tabulæ thin, very close, strongly arched in the center, vesicular at the base.

In the Onondaga limestone of Canada, Michigan and the Falls of the Ohio region.

101. **M. cylindrica** (Michelin). Devonic.

Corallites subcylindrical; on the interior are regular annulations

Digitized by Google

which occupy the same level in the adjoining tubes. Principal tabulæ numerous, slightly arched, uniting with the incomplete one.

In the Onondaga limestone of Michigan, Ohio and Kentucky, etc.

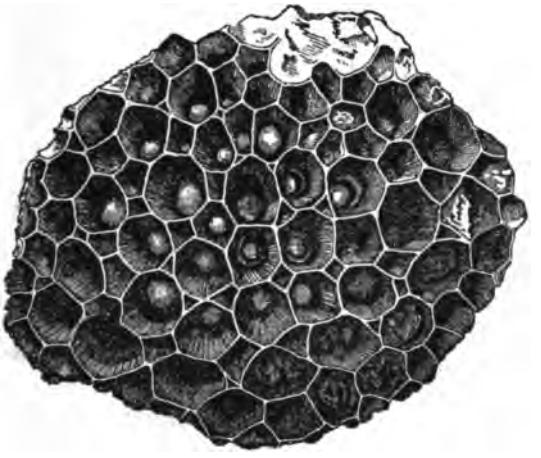


FIG. 144. *Michelinia convexa* (after Billings).

102. **M. favositoidea** Billings. Devonic.

Calices 4–6 mm. in diameter; tabulæ horizontal, pores numerous, crowded. (Forms transition type to *Favosites*.)

In the Onondaga limestone in New York, Canada, and the Falls of the Ohio.

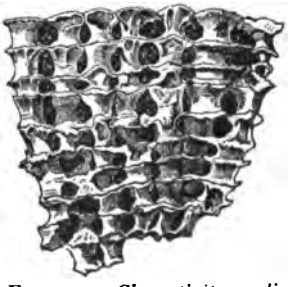


FIG. 145. *Chonostigites ordinatus* (after Billings).

XXXVIII. CHONOSTEGITES E. & H.

Coral heads composed of cylindrical tubes, either closely adjoining or distinct and expanding at regular intervals into connecting horizontal plates, which are pierced by canal-like pores. Tabulæ as in *Michelinia*, septa represented by rows of spinules New buds arise from the connecting plates. Devonic.

103. **C. clappi** E. & H. Devonic.

Tubes 5 mm. or more in diameter, connecting plates crowded, giving the whole a very compact appearance.

In the Onondaga limestone of western New York, Ontario, and Falls of the Ohio.

Digitized by Google

104. **C. ordinatus** (Billings). (Fig. 145.) Devonic.

Tubes smaller and more distant and plates more widely separated than in preceding. Whole aspect more loosely aggregated.

In the Onondaga beds of western New York and Canada.

XXXIX. Thecia E. & H.

Generally massive corals composed of prismatic thick-walled tubes with funnel-form calices. Base with a wrinkled peritheca. Septa 12, strong, uniting in adjoining calices across the intervening space. Tabulæ and mural pores as in *Favosites*. Sil.–Dev.

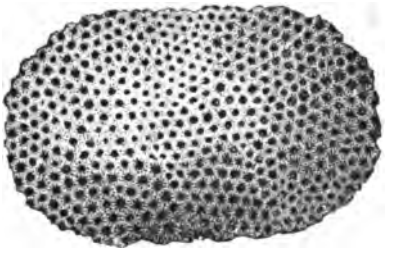


Fig. 146. *Thecia major* (Ind. Geol. Surv.).

105. **T. major** Rom. (Fig. 146.) Siluric.

Corallites 2 mm. in diameter; septa extend half way to center, their edges with two rows of granulose spinules.

In the Niagara beds of Michigan, Tennessee, the Falls of the Ohio and other regions.

106. **T. minor** Rom. (Fig. 147.) (*T. Swinderana?* (Goldf.).) Siluric.

Tubes about 1 mm. in diameter, otherwise similar to the preceding. Occurs with the preceding.

107. **T. ramosa** Rom. Devonic.

Branching, cylindrical stems from half an inch to two inches in diameter. Calices unequal from 1 to 2 mm. in diameter.

In the Onondaga beds of Michigan and the Falls of the Ohio.

Fig. 147. *Thecia minor* (enlarged).

XL. Alveolites Lamarck.

Massive or arborescent coralla. Tubes thin-walled, closely appressed, the calices oblique, compressed, triangular or crescentic. Septa rudimentary. Tabulæ complete; mural pores large but irregularly disposed. Sil.–Dev.

108. **A. niagarensis** Rominger. Siluric.

Hemispheric masses of concentric laminæ, with epitheca on

Digitized by Google

lower side. The large marginal pores cause a pouch-like dilation of the tube-wall.

In the Niagara group of Michigan and the falls of the Ohio.

109. **A. squamosus** Billings. Devonic.

Differs from the preceding in the greater horizontal expansion (5–6 in.) as compared with the thickness (1 in.) also in the great obliquity of the apertures, and in the absence of the pouch-like protuberances. Septal spines present. Greatest diameter of tubes .5 to 1 mm.

In the Onondaga formation of New York, Canada, Michigan, Ohio, Kentucky, etc.

110. **A. goldfussi** Billings. Devonic.

Flattened or disk-like expansions like the preceding with a basal epitheca. Tubes larger (1.5 to 2 mm.), oblique and in various stages of compressions in the same specimen.

In the Hamilton group of New York, Canada, Michigan, Iowa and in strata of similar age near Louisville, Ky.

XLI. Cladopora.

Coral composed of branching stems or flattened expansions, with thick-walled elongate, conical tubes, opening oblique to the surface, with dilated orifices. Mural pores and occasional tabulae present. Sil.–Dev.

Flattened Expanded Species.

111. **C. laqueata** Rominger. Siluric.

Expansions composed of round or compressed elliptical stems from two to four millimeters in diameter and uniting repeatedly so as to form a coarse network. Orifices of tubes distant with a strong lip, oval, transverse to the branches, width nearly a millimeter.

In the Niagara group of Michigan and at the falls of the Ohio.

112. **C. lichenoides** Rominger. Devonic.

Irregular expansions with peritheca on the under side. Tubes flattened, extending outward, prostrate but bending upward at the ends. Orifices oblique or at times nearly at right angles to the tube, and polygonal.

In the Onondaga beds of New York, Canada, Michigan and the Falls of the Ohio.

Digitized by Google

113. **C. fisheri** Billings. Devonic.

Flat leaf-like expansions attached at one point to foreign bodies, and with oblique orifices on both sides.

In the Onondaga (?) beds of Kentucky and Indiana and in the Hamilton group of Canada, etc.

ROUND STEMMED SPECIES.

114. **C. seriata** Hall. (Fig. 148.) Siluric.

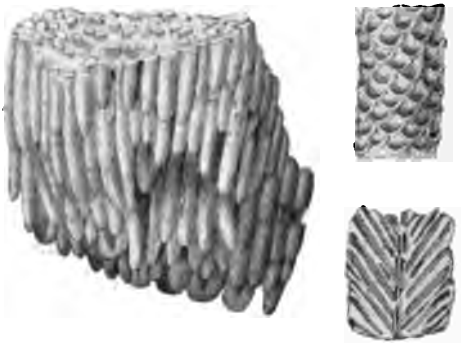


FIG. 148. *Cladopora seriata* (N. Y. St. Geol. Surv.).

Nearly parallel crowded branches, forming a glomerate mass, the branches sometimes bifurcating. Calices in alternating series with projecting circular lip.

In the Niagara group of New York, Canada, etc.

115. **C. cryptodens** (Billings). (Fig. 149.) Devonic.

Cylindrical bifurcating branches from five to ten millimeters in

FIG. 149. *Cladopora cryptodens* (after Billings).

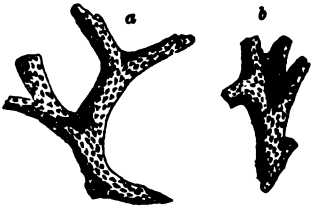


FIG. 150, *a–b*. *Cladopora labiosa* (after Billings).

diameter. Tubes with oblique dilated orifices from 1 to 1½ mm. in diameter.

Digitized by Google

In the Onondaga beds of New York, Canada, Michigan, and Western States.

116. **C. labiosa** (Billings). (Fig. 150, *a–b.*) Devonic.

Stems smaller and more frequently branching, often reuniting. Oblique (2 to 5 mm. in diameter) subcircular orifices with a prominent convex lip.

Abundant in the Onondaga of New York, Canada, Michigan and the Falls of the Ohio.

117. **C. roemeri** (Billings). Devonic.

Cylindrical or compressed stems, about 5 mm. or less in diameter with large oblique orifices, which merge into an indefinite interstitial surface or into angular pits.

In the Hamilton group of Canada and at the Falls of the Ohio.

118. **C. pulchra** Rominger. Devonic.

Similar to preceding but with circular orifices, more than a tube-diameter apart, and often at the summit of a small elevation.

In the Onondaga of Canada, Michigan and the Falls of the Ohio.

119. **C. robusta** Rominger. Devonic.

Large compressed cylindrical stems from 10 to 20 mm. thick and often forming net-like expansions covering several square feet. Oblique orifices with strong semicircular lips.

In the Onondaga beds of Michigan and the Falls of the Ohio, and in the Hamilton of Michigan.

XLII. Striatopora Hall.

Coral stock of simple dividing cylindrical branches, with thick-walled corallites, opening in rounded apertures, which are surrounded by polygonal depressed calices, the sides of which are striated by rudimentary septa. Occasional septal spines, tabulæ and mural pores present. Sil.–Dev.

120. **S. flexuosa** Hall. (Fig. 151.) Siluric.

Bifurcating branches. Polygonal expansion of cells deep, and bounded by angular ridges, vertically striate, the striæ becoming fainter upward. Calices circular at the base.

In the Niagara beds of New York, etc.

121. **S. linnæana** Billings. Devonic.

Orifices of unequal size through intercalation of smaller ones, moderately oblique, 2 mm. in diameter and narrowing in diameter.

Digitized by Google

Twelve radial furrows, not always preserved in fossilization, mark the orifices and between them are rows of spinules.

In the Hamilton group of Canada and Michigan and in Devonic beds of somewhat earlier age at the Falls of the Ohio.

FIG. 151. *Striatopora flexuosa* (N. Y. Geol. Surv.).

XLIII. TRACHYPORA E. & H.

Corallum consisting of branching cylindrical stems, which are made up of polygonal corallites with very thick walls, and circular calices, which are superficially far apart. Scattered mural pores, remote tabulæ, and rows of spines representing the septa, are characteristic. Dev.

FIG. 152. *Trachypora ornata* (= *T. limbata* Hall) (Pal., N. Y.).

122. **T. ornata** Rom. (Fig. 152.) Devonic.

Stems 10 to 20 mm. in diameter, orifices circular or oval, generally slightly elevated, irregularly dispersed, the interspaces wider than the diameter of orifice, which is about 1½ mm. Granules and short radial ridges surround the orifices.

Common in the Hamilton group of New York, also more rarely in Canada and Michigan.

123. **T. elegantula** Billings. Devonic.

Stems 2 to 5 mm. in diameter, orifices in four rows, oval and partly edged by an elevated rim.

Hamilton group of Michigan and Canada.

Digitized by Google

XLIV. Halysites Fisher.

Corallum composed of cylindrical or compressed corallites, which are joined into intersecting and anastomosing laminæ of single layers of tubes united along the whole of their adjoining side.

Fig. 153. *Halysites catenulatus* (N. Y. Geol. Surv.).

The tubes are covered by a continuous peritheca on their free sides. No mural pores; tabulæ well developed; septa obsolete or in cycles of 12. Ord.–Sil.

124. **H. catenulatus** (Linn.). (Fig. 153.) (Ord.) to Siluric.

Tubes oval in section united by their narrower sides, or with a minute closely tabulate tube intervening. Epitheca with fine and occasionally coarse lines of growth; meshes formed by tubes, large, irregular and varying in size.

In the Ordovicic beds of Anticosti, Wisconsin, Colorado, but especially in the Middle Siluric of Europe and North America generally.

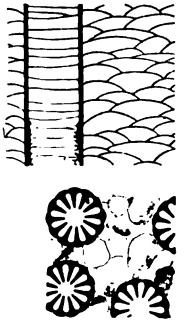


Fig. 154. *Lyellia americana*, vertical and transverse sections enlarged (after Lambe).

Octameral Corals.

XLV. Lyellia E. & H.

Coral head consisting of numerous cylindrical tubes, growing parallel and united by vesicular cœnenchyma, septa 12, short, tabulæ irregular. Siluric.

125. **L. americana** E. & H. (Figs. 154–155.) Siluric.

Tubes 1½ to 2 mm. in diameter, separated by two tube-diameters or something less. Septa comparatively short, cœnenchyma of fine cysts.

Digitized by Google

In the Niagara group of Michigan, Iowa and the Falls of the Ohio. Also at Anticosti.

XLVI. Heliolites Guettard.

Corallum compound, varying from spheroidal to flabellate, with large cylindrical macrocorallites, furnished with twelve infoldings of the wall, or pseudosepta, and numerous angular microcorallites

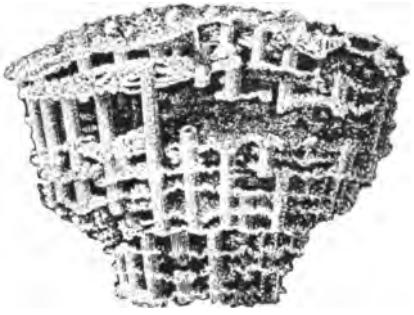


Fig. 155. *Lyellia americana* (Ind. Geol. Surv.).

investing the larger ones. Tabulæ in both corallites, more numerous in the smaller. No mural pores. Basal peritheca present. Ord.?–Dev.

126. **H. megastoma** McCoy. Siluric.

Convex heads with the macrocorallites about 2 mm. in diameter and distant somewhat less. Twelve very short pseudosepta. Form subglobular.

In the Niagara group of New York, Canada, Michigan, Iowa, Wisconsin, etc.

127. **H. interstinctus** Linn. (Figs. 156, 158, *a*, *b*.) Siluric.

Discoid or in leaf-like expansions with a basal peritheca. Macro-

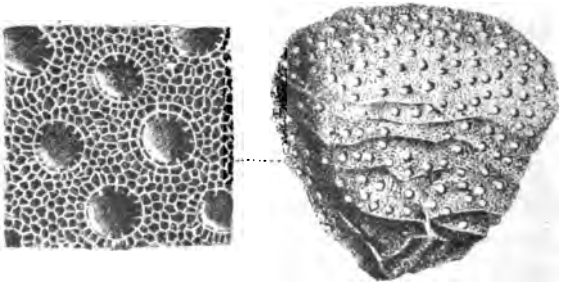


Fig. 156. *Heliolites interstinctus*, with part of surface enlarged (after Roemer.)

Digitized by Google

corallites slightly larger than in preceding, and somewhat more distant. Pseudosepta nearly reaching the center in well-preserved specimens. Microcorallites polygonal.

FIG. 157. *Heliolites elegans* (N. Y. Geol. Surv.).

In the Niagara group of Michigan, Indiana, Kentucky, Tennessee, etc.

128. **H. elegans** Hall. (Fig. 157.) Siluric.

Hemispheric coralla with macrocorallites a little over .5 mm. in diameter, and pseudosepta in the form of oblique spines and reaching half way to the center. Microcorallites crowded, minute.

In the Niagara group of New York, Michigan, Indiana, Kentucky, etc.

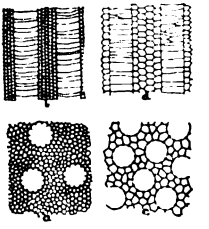


FIG. 158, *a*, *b*. *Heliolites interstinctus*; *c*, *d*, *Plasmopora follis*, vertical and horizontal sections enlarged (after Lambe).

XLVII. PLASMOPORA E. & H.

Differs from *Heliolites* in having twelve well-developed vertical rows of spinulose pseudosepta and cœnenchyma composed of intersecting plates which however form no true microcorallites, and whose tabulæ become more or less continuous, producing a vesicular tissue. Ord?–Dev.

129. **P. follis** E. & H. (Fig. 157, *c*, *d*.) Siluric.

Tubes from 1 to 1.5 mm. in diameter with circular crenulated

Digitized by Google

orifices, and separated by an equal width. Growth in pyriform or subcylindrical club-shaped masses, with a rudimentary peritheca at the conical base.

In the Niagara beds of Michigan — more commonly in the same beds of Indiana, Kentucky and Tennessee.

XLVIII. TETRADIUM Dana.

Massive heads composed of numerous long, slender, prismatic and thin-walled corallites, quadrangular or petaloid in section and with four primary septa and numerous tabulæ. Increases by fission. Ordovicic.

FIG. 159. *Tetradium fibratum.*

T. fibratum Safford. (Figs. 159, 160.) Ordovicic.

Septa nearly reaching center; diameter of corallites 0.04 inch.

In Stones River and Black River of New York, Canada, Tennessee and other localities.

Hexameral Corals.

XLIX. PARASMYLIA E. & H.

Cylindrical or conical, simple corals with a scar of attachment at the base. Calyx circular, with granular septa and a spongy columella. Epitheca absent or rudimentary, and costæ strong. Cretacic.

130. **P. austinensis** Roem. Cretacic.

Top-shaped corals attached by a broad base, above which it is contracted, strong equal costæ. Calyx slightly compressed with septa in four cycles.

FIG. 160. *Tetradium fibratum*, cross-section much enlarged (after Lambe).

In the Edwards limestone (Lower Cretacic) of Texas.

131. **P. texana** Vaughan. (Fig. 161.) Cretacic.

Differs from the preceding in having costæ alternating large and small.

In the Buda limestone (Lower Cretacic of Shoal Creek, Texas).

L. PLEUROCORA E. & H.

Branching cylindrical corals with a thick compact wall without epitheca. Columella of numerous points (papillose); septa granular, projecting above the calyx. Costæ distinctly wavy. Cretacic.

Digitized by Google

132. **P. coalescens** Roem. Cretacic.

Slender cylindrical, much branching corals with calices 3 mm. in diameter — septa not reaching to center, which is occupied by spongy columella.

In the Edwards limestone (Lower Cretacic) of Texas.

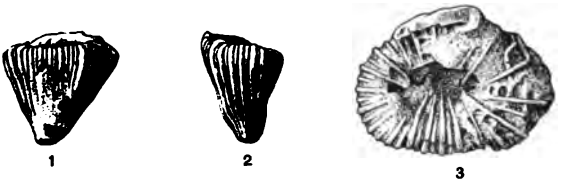


FIG. 161. *Parasmylia texana* (Vaughan, Bull. U. S. G. S.).

LI. CLADOPHYLLIA E. & H.

Branching corals with cylindrical stems multiplying by fission. Calices circular with a rudimentary columella or none; a well-developed epitheca is present. Cret.–Recent.

133. **C. furcifera** Roem. (Fig. 162.) Cretacic.

Calices 4 to 6 mm. in diameter. No columella, septa in 3 cycles. Growth a regular forking, with uniform branches. Epitheca concentrically wrinkled.

In the Edwards limestone (Lower Cretacic) of Texas.

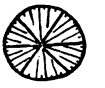


FIG. 162. *Cladophyllia furcifera*, section of calyx, × 2.

LII. SEPTASTRÆA d'Orbigny.

Compound corals, with corallites prismatic from crowding. Calices of moderate depth with simple septa,

FIG. 163. *Septastræa marylandica* (Md. Geol. Surv.) reduced.

Digitized by Google

the longer of which unite in the center, where they often form a pseudocolumella. No true columella or pali occur. Tertiary.

134. **S. marylandica** (Conrad). (Fig. 163.) Miocenic.

Compressed stems with short, rounded branches, or large flattened lobate or digitiform expansions. Corallites averaging 5 or 6 mm. in diameter. Twelve large and a similar number of smaller septa occur; sometimes a third series.

Abundant in the St. Mary's Miocene formations of various parts of the Atlantic coast.

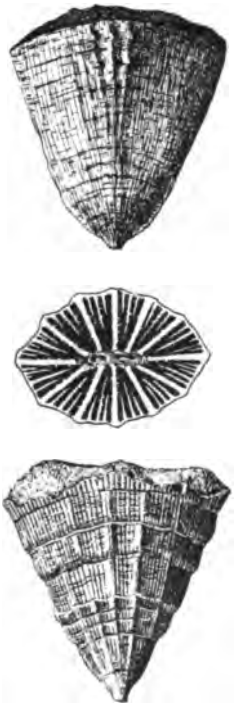


FIG. 164. *F. abellum cuneiforme*, two varieties, with calyx of *F. lerchi* (after Vaughan, Mon. U.S.G. S.).

LIII. FLABELLUM Lesson.

Simple wedge-shaped compressed corals free or attached, with numerous septa, and a compressed columella. A wrinkled epitheca sometimes with spinous processes occurs. Tert.–Recent.

135. **F. cuneiforme** Lonsdale. (Fig. 164.) Eocenic to Oligocenic.

Base with a short prolongation of attachment; exterior of compressed wedge-shaped structure marked by strong ridges or costæ which are largest in the middle. First three cycles of septa form the columella by fusion of their inner margins. Claibornian, Jacksonian and Vicksburgian groups of South Carolina, Alabama, Mississippi, Louisiana, Arkansas and Texas. Several distinct varieties are recognized.

LIV. PLATYTROCHUS Milne-Edwards & Haime.

Simple cuneiform corals, with a columella formed of the fused inner edges of the septa. Externally the septa are represented by thick costæ, while within the outer wall their margins are carinated. Tertiary.

136. **P. stokesi** (Lea). (Fig. 165.) Eocenic.

Small, with the base drawn out into a wedge nearly as wide as the coral above. Septa and costæ 24, nine of which on the mid-

Digitized by Google

dle of each broad face, converge and unite downward, while those on either side become broader. Surface rough with granules. Columella papillose.

In the Claibornian group of South Carolina, Alabama, Mississippi and Texas.

LV. Discotrochus Milne-Edwards & Haime.

Free, disk-like corals, with a flat base and slightly arched upper surface. Septa carinate, radial, the longer joining the papillose columella. Costæ simple. Tertiary.

137. **D. orbignianus** E. & H. (Fig. 166.) Eocenic.

Base with the large unequal costæ becoming indistinct near the concave center. Diameter 6 mm., height 1.5 mm.

Fig. 165. *Platytrochus stokesi* (after Vaughan, enlarged).

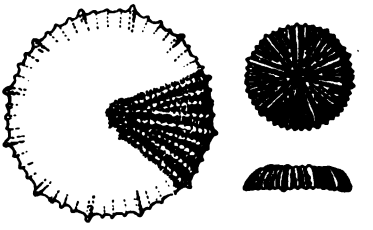


Fig. 166. *Discotrochus orbignianus*, with partial enlargement (after Vaughan).

In the Lower Claibornian of Alabama, Mississippi, Louisiana and Texas.

LVI. Turbinolia Lamarck.

Small, free, conical corals with a circular calyx. Septa prolonged externally into strong costæ. Septa in several cycles. Alternate septa triple from union with smaller ones, columella well developed. Tert.–Recent.

138. **T. pharetra** Lea. (Fig. 167.) Eocenic.

Twenty-four rounded and prominent costæ, with entire margins, twelve of which become larger basally and only six occurring at the base. A double row of pores occurs in the furrows between the costæ. Columella slightly projecting in the form of a star, with six rays, each of which fuses with a principal septum.

Fig. 167. *Turbinolia pharetra* (after Vaughan, enlarged).

Digitized by Google

In the Claibornian and Jacksonian groups of Alabama, Mississippi, Louisiana and Texas.

LVII. Oculina Lamarck.

Composite corals generally in the form of branching stems with the calices spirally distributed over the stem, generally on crater-

Fig. 168. *Oculina vicksburgensis.*

Fig. 169. *Oculina mississippiensis.*

(After Vaughan, Mon. U. S. G. S.)

like elevations and separated by dense layers of cœnenchyma. Septa in several cycles, the longer reaching the center which is occupied by a papillose columella surrounded by a cycle of vertical rods or pali. Tert.–Recent.

139. **O. vicksburgensis** (Conrad). (Fig. 168.) Oligocenic.

Branches 20 to 30 mm. in thickness. Circular calices separated by once or twice their diameters or more, shallow, but often with a prominent margin. Feeble flexous striæ radiate from the calices on the cœnenchyma. Diameter of adult calyx averaging 4 mm.

In the Vicksburgian and Red Bluff beds of Mississippi.

140. **O. mississippiensis** (Conrad). (Fig. 169.) Oligocenic.

Calices strongly projecting, crowded, with thin septa. Costal striæ faint or obsolete.

In the Vicksburgian group of Mississippi.

Digitized by Google

LVIII. Astrohelia E. & H.

Similar to *Oculina*, but with the calices merely excavated, rarely raised on crater-like elevations. Columella spongy. Tertiary.

Fig. 170. *Astrohelia palmata* (Md. Geol. Survey) reduced.

141. **A. palmata** (Goldfuss). (Fig. 170.) Miocenic.

Branching, often coalescing, or in palmate expansions. Calices circular, excavated, septa in three cycles, the first and second reaching the columella.

In the Choptank and Calvert formations of the Miocene of the Atlantic coast.

LIX. Balanophyllia Wood.

Simple conical corals with a broad base of fixation. Septa very numerous, closely crowded and partly fused together. Columella spongy. Epitheca often present, structure porous. Eocenic–Recent.

142. **B. desmophyllum** E. & H. (Fig. 172.) Eocenic.

Basal portions cylindrical, becoming conical upwards. Section elongate, elliptical with rather deep calyx. Septa thin, costæ fine. Epitheca rudimentary or absent.

In the Chickasawan and Claibornian beds of Alabama, Mississippi, Texas and in Maryland.

143. **B. irrorata** (Conrad). (Fig. 171.) Eocenic.

Slender cylindro-conical, curved, cross-section elliptical, epitheca on basal portion.

Digitized by Google

In the Claibornian and Jacksonian beds of Alabama, Louisiana and Mississippi. Varieties also found in Texas.

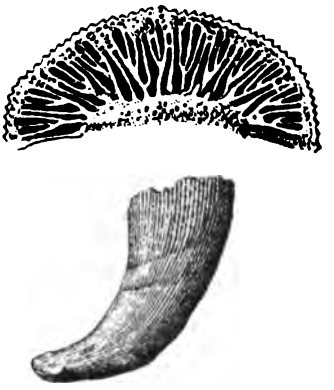


Fig. 171. *Balanophyllia irrorata* with enlargement of calyx (Vaughan).

144. **B. haleana** (E. & H.). (Fig. 173.) Eocenic.

Conical, slightly curved, broadly elliptical in sections, basally attached. Costæ dividing upwards. Septa crowded, extremely thin, with granulated surfaces. Columella large, spongy but dense. Basal epitheca present.

Common in the Chickasawan of Alabama.

LX. EUPSAMMIA E. & H.

Like *Balanophyllia*, but acutely pointed and free. Septa of the last cycle stouter than the rest. Columella present or absent. Tert.–Recent.

145. **E. elaborata** (Conrad). (Fig. 174.) Eocenic.

Conical with elliptical section; finely perforated, costæ trifurcating upwards. No epitheca. Spongy columella, and thin anastomosing septa; wall spongy.

In the Chickasawan beds of Maryland, Virginia and Alabama.

FIG. 172. *Balanophyllia desmophyllum.* FIG. 173. *Balanophyllia haleana.* FIG. 174. *Eupsammia elaborata.*

(After Vaughan.)

LXI. ENDOPACHUS Lonsdale.

Corals with the general form of *Flabellum*, but with the porous

Digitized by Google

wall structure and septal arrangement of *Eupsammia*. Lateral wings often developed. A compressed spongy columella occurs. Tertiary.

146. **E. maclurii** (Lea). (Fig. 175.) Eocenic.

Cuneate, with subparallel margins, sides and ends rounded.

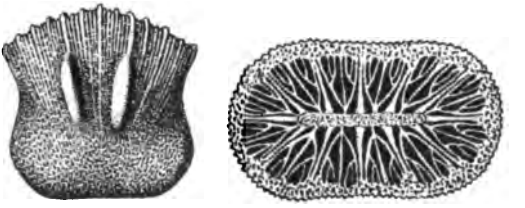


FIG. 175. *Endopachus maclurii* (after Vaughan).

Lateral wings well developed. Columella narrow and elongate in long axis of corallum; very vesiculate.

In the Claibornian and Jacksonian beds of Alabama, Mississippi, Louisiana and Texas.

Digitized by Google

ABSTRACTS.

ANALYTICAL CHEMISTRY.

By E. Waller.

Cleansing Metal Apparatus. Deussen (*Zts. Angew. Chem.*, XVIII., 813). The author finds that rusty and corroded apparatus, such as ring-stands, Bunsen burners, etc., may be satisfactorily cleansed from rust, etc.. by use of a 2- to 5-per cent. solution of HF, which readily dissolves and loosens the rust. Greasy or fatty matter must of course be removed, The articles are soaked over night in the acid and then brushed or rubbed off. Acid of that strength readily removes iron stains from linen or cotton goods without affecting the strength of the fiber, and also is harmless on the skin of the hands.

Periodate as a Reagent. Benedict (*Am. Chem. Jour.*, XXXIV., 581). One or two drops of a N/10 solution of potassium periodate (KIO_4) added to a neutral or ammoniacal solution of Mn gives a red precipitate, or, if Mn is small, a red coloration. If neutral, the color persists. In presence of NH_3 it slowly blackens. NaOH blackens it almost immediately; HCl dissolves it. *Per contra*, Mn salt may be used as a test for periodates.

Zn is precipitated white by KIO_4, except in presence of NH_4Cl and NH_4OH, in the cold. On boiling the precipitate forms.

With Ni salts KIO_4 gives a light green precipitate; the Co precipitate is dark brown and dissolves on boiling to a greenish-black solution. By this means 0.1 per cent. Co can be detected in Ni solutions.

Ferrous Oxalate for Standardizing. Barbieri and Neppi (*Rendiconti Soc. Chim. Rom.*, III., 16). This salt is claimed to be free from the various objectionable features of the other substances used for standardizing permanganate, etc. It is easily prepared by precipitating a ferrous salt with $H_2C_2O_4$. The yellow crystalline precipitate does not oxidize in air and has the constant composition $FeC_2O_4.2H_2O$. Dissolved in dilute H_2SO_4 in the cold it reacts with permanganate thus:

$$6KMnO_4 + 10FeC_2O_4 + 24H_2SO_4 = 3K_2SO_4 + 6MnSO_4 + 5Fe_2(SO_4)_3 + 20\,CO_2 + 24H_2O.$$

Ammonia in Waters. Cavalier and Artus (*Bull. Soc. Chim.*, XXXIII., 745). The authors criticize adversely the method of Trillat and Forchet (vid. Quarterly, XXVI., 418) by means of hypochlorite and formation of NI_3. Most waters require concentration for the test, also the instability of the NI_3 renders a quantitative estimation difficult.

Sodium—Modification of Fremy's Reagent. Bougault (*J. Pharm. Chim.* XXI., 437). Mix 10 c.c. of a 33.3 per cent. solution of K_2CO_3 with 45 c.c. of a 10 volume solution of H_2O_2 and to this add 1 gm. $SbCl_3$ Warm gently with a little agitation when the precipitate gradually redissolves, with effervescence of O. After 5 or 10 minutes heating, cool and filter. The solution to be tested must be small in bulk, neutral or alkaline

Digitized by Google

and free from salts of the heavy metals. Use not over 0.1 c.c. of the reagent at a time. Bring the mixture to a boil after mixing and then cool. Much K salts retard or prevent the formation of the precipitate.

Potassium. New Reagent. Alvarez (*C. Rend.*, CLX., 1186). A 5 per cent. solution of Eikonogen (sodium amino naphthol sulphonate) produces in neutral solutions a white brilliant crystalline precipitate. The formation of the precipitate is slow, but is favored by agitation. NH_4 and Mg do not interfere though some of the heavy metals give similar precipitates with the reagent.

Lime Analysis. Sugar Test. J. Watson at the July meeting, 1905, of the Chem. Met. and Min. Soc. of South Africa (*Jour*, VI., 19) criticises adversely the sugar test for commercial lime. He contrasts results obtained by gravimetric analysis with those obtained by shaking a weighed amount (presumably 2 gm.) with 20 gm. of sugar dissolved in 1 liter of water — settling, and then titrating aliquot portions of the clear solution. The results were irregular, and usually too low. Methyl orange as an indicator appeared to be better than phenolphthalein. The results were best on the best burned limes. $CaCO_3$ and also MgO appeared by his experiments to be soluble in the sugar solution.

Mr. A. L. Edwards remarked in the discussion that commercial lime. containing over 52 per cent. CaO were seldom obtained in the Rand (A part of the error found by Mr. Watson in the sugar method seems possibly attributable to tests on the solution after settling, but without filtering. It is not made clear whether he filtered in every case. *Abs.*)

Distinguishing Calcite from Dolomite. Thugutt (*Centr. Min.*, 1905, 265). A splinter of calcite immersed in a 10 per cent. solution of Fe_2Cl_6 becomes soon coated with a brownish deposit of hydrated Fe_2O_3, whereas dolomite does not show this reaction.

Iron in Pyrolusite. Corminboeuf (*Ann. Chim. Anal. App.*, X., 51). Treat 2 gm. of the mineral with 25 to 30 c.c. conc. HCl, after slightly ign ting the same. Nearly neutralize with Na_2CO_3 and add excess of milk of ZnO. No Mn precipitates with the $Fe_2(OH)_6$. Dissolve the precipitate (together with excess of ZnO) in H_2SO_4, reduce and titrate Fe.

Iron and Aluminum. Deussen (*Zts. Angew. Chem.*, XVIII., 815). After weighing an ignited mixture of Fe_2O_3 and Al_2O_3 it is usually recommended to render soluble by fusion with $KHSO_4$, remove Pb by H_2S, reduce and titrate Fe.

The author advises the use of KHF_2 instead of $KHSO_4$ (about 1 gm. for a precipitate of 0.5 gm. or less) as it does not attack the platinum and makes the manipulation more rapid and convenient. After the fusion some conc. H_2SO_4 may be added, and on heating for a short time HF is expelled, when the Fe may be reduced by SO_2, in a beaker, excess of SO_2 driven out by CO_2 and permanganate titration applied.

Iron, Aluminum or Chromium from Magnesium or from manganese, zinc, nickel, copper, etc. Jannasch and Rühl (*J. pr. Chem.*, LXXII., 1), Jannasch and Cohen (*ib.*, 14). Acidify with HCl, add 5 or 6 times as much hydroxylamine hydrochloride, boil, and precipitate with strong NH_4OH. Wash by decantation with boiling water containing a little NH_4OH if Zn is present. In a filtrate containing Cu the metal may be separated by NH_4CNS. If the filtrate contains Zn, the hydroxylamine should be destroyed by use of Br when it is necessary to concentrate by evaporation.

Digitized by Google

Manganese in Waters. Croner (*Chem. Centr.*, 1905, II., 74). Acidify 100 c.c. of the water with HCl, filter, add 2 c.c. of strong solution of tartaric, and then a slight excess of NH_4OH. Then stir in 2 c.c. of a saturated solution of ferrocyanide. A white turbidity will appear if Mn is present, developing more or less quickly according to the proportion of Mn.

Manganese in Cyanide Solutions Clennell (*Eng. and Min. Jour.*, LXXVIII., 827). Boil 100 c.c. with conc. HNO_3 and add PbO_2 which will give the permanganate color. Compare with a $K_2Mn_2O_8$ solution of known strength. Mn interferes with the extraction of gold.

Nickel — Qualitative. Tschugaeff (*Ber.*, XXXVIII., 2520). Adding ammonia and ammonium acetate, and then some pulverized alpha dimethyl glyoxime, and boiling for a short time, affords a scarlet precipitate. If the Ni is small in amount, the solution may be yellow, but on cooling the red compound separates out.

The dioxime is $CH_3.C(NOH)C(NOH)CH_3$. It is now on sale by manufacturers of fine chemicals One part of Ni in 400,000 can be detected. Co up to ten times the amount of Ni does not interfere. If larger proportions are present, the solution must be poured off after cooling, and the precipitate adhering to the sides of the vessel washed with water. If Ni is present, the deposit shows a pink coloration not removable by cold water.

Electrolytic Separation of Nickel from Zinc. Hollard and Bertiaux (*C. Rend.*, CXXXVIII., 1605). Zinc ammonium nitrite is not electrolyzed, whereas the corresponding Ni compound is. To the sulphate solution of the two add 5 gm. $MgSO_4$, 25 c.c. NH_4OH (22° Be) and sufficient dilute H_2SO_4 to acidify. Then add 12 gm. NH_4NO_3 and 25 c.c. of saturated aqueous solution of SO_2. Boil until the odor of SO_2 is gone, dilute, and add 25 c.c. NH_4OH The volume should be about 300 c.c. Electrolyze at 85° C. with a current of one ampere.

Zinc in Zinc Aluminum Alloys. Seligman and Willott (*J. S. C. L.*, XXIV., 1278) Dissolve 0.5 gm. of turnings in 25 c.c. of a 25 per cent. solution of NaOH in a 400 c.c. beaker. After solution, dilute to 300 c.c. with boiling water and allow undissolved Cu, Fe, etc., to settle out. Filter, dissolve the residue in a little HCl — dilute to 20 c.c. — just neutralize with NaOH and then add 2 c.c. in excess. Filter into the main solution, which is then warmed, and a current H_2S passed. When there is seen the formation of a skin at the point where the gas bubbles burst, all the Zn has been converted into ZnS, and the Al is beginning to come down. Stop the H_2S and allow to settle for five minutes. $Al_2(OH)_6$ up to 10 per cent. does not interfere with the titration of Zn. Filter (washing is unnecessary) dissolve the precipitate in 8 c.c. HCl. The solution and washings (with boiling water) are brought to 250 c.c., 5 gm. NH_4Cl are added and the solution at once titrated with standard ferrocyanide 22 gm. per liter. For the spot tests the author prefers a slab of paraffin, or a white porcelain plate covered with a thin film of the paraffin. The presence of minute traces of Fe is of advantage, affording as it does a faint bluish tinge to the solution, which disappears just before the end point is reached.

Copper by the Iodine Method. Moser (*Zts. Anal. Chem.*, XLIII., 597). The interference with accuracy in this method caused by the presence of Fe, or As in the solution, can be annulled by addition of

Digitized by Google

sodium pyrophosphate in amount sufficient to redissolve the precipitate which at first forms in the acetic solution when otherwise ready for adding KI and titration.

Electrolytic for Lead and Copper. Guess (*Trans. Am. Inst. Min. Eng.*, Bimonthly Bull., 1905, 1239). The electrodes are made of 0.001 inch platinum foil, sand-blasted to make the deposits adhere more firmly, and corrugated lengthwise to impart the necessary rigidity. Anodes are 12.5 cm. long, of which one half is 4 cm. wide and the other half 0.7 cm. wide. The immersion area is about 50 sq. cm. With this is used two cathodes each 0.5 cm. wide and 12.5 cm. long with a corrugation in the middle. The anodes weigh about 1.5 gm. each. Slotted aluminum terminals are used to make the connections. For Pb determinations 0.855 gm. of the ore is weighed in the battery beaker and digested with 10 c.c. HNO_3. After boiling and consequent decomposition 10 to 20 c.c. NH_4NO_3 solution (saturated) containing 20 per cent. of free NH_3 is added to dissolve the $PbSO_4$. After solution the beaker is nearly filled with water and 10 to 20 c.c. HNO_3 added. A current of 1.5 to 2 amp. has been found to be best. With this PbO_2 deposits completely on the anodes in two hours. The theoretical factor for calculating PbO_2 to Pb is 0.866. In practice 0.855 is found to be more accurate; so that when 0.855 gm. of ore is used for a determination, the weights are convertible to percentages by shifting the decimal point. As and Te, if present, must be removed before electrolyzing or they will prevent deposition of the PbO_2. Bi, if present, gives a bluish color to the coating. Properly sand-blasted anodes will retain 0.250 to 0.600 gm. PbO_2. The deposits are washed with water, then with alcohol, dried and weighed. Electrodes of the same make are used for Cu. The speed of deposition is increased by use of a stronger current, and at the same time an addition of so-called "dope." This latter is made by boiling "Standard Oil Co.'s Hard oil No. 4" with HNO_3, cooling and removing the greasy portion. The solution has a deep red color. The ore is weighed into battery beakers, 7 c.c. HNO_3 added and boiled until nitrous fumes have been expelled. 2 c.c. of "dope" is then added, the beakers filled up with water, and, after settling for a moment the solution is electrolyzed at 1.5 amp. for three hours, which proves to be sufficient. In presence of the "dope" As or Sb do not prevent the obtaining of bright deposits.

Lead as Sulphate. Belton (*Chem. News*, XCI., 191). In the ordinary method evaporation with H_2SO_4 to fumes, diluting, and filtering off $PbSO_4$, results in presence of K salts are erroneous, since $K_2Pb(SO_4)_2$ separates, unless the dilution, etc., is conducted at boiling temperature.

Bismuth as Phosphate. Moser (*Zts. Anal. Chem.*, XLV., 19). The phosphate (which invariably separates as $BiPO_4$) is insoluble in HNO_3 even moderately strong, especially when some alkaline phosphate is present in the solution. Bring the solution to boiling, and add slowly with stirring a N/5 solution of $(NH_4)_2HPO_4$ in slight excess. A white heavy crystalline precipitate of $BiPO_4$ separates, which settles readily, and can be then filtered. If Cu or Cd are present, digest the precipitate (after pouring off the supernatant liquid) with 50 to 100 c.c. of N/10 HNO_3 for 5 or 10 minutes add a little more $(NH_4)_2HPO_4$ solution, settle and filter. Though it is possible to ignite the precipitate, paper and all, it is better to separate the precipitate from the filter, incinerate the paper, and then add the precipitate and ignite the whole.

Digitized by Google

Bismuth Determinations. Staehler and Scharfenberg (*Ber.*, XXXVIII., 3862).

The phosphate is somewhat soluble in HNO_3 of higher sp. gr. than 1.02 to 1.03 and also in HCl, but the authors find it is practically insoluble in H_3PO_4, so that by adding a sufficient excess of Na_3PO_4 or of Na_2HPO_4 Bi can be completely precipitated. The best mode of manipulation was found to be this: The solution, containing about 0.2 gm. Bi or less was diluted to 300 to 400 c.c. and heated to boiling. If any basic salt appeared, it was removed by adding a little HNO_3. A boiling hot solution of Na_2HPO_4 (or Na_3PO_4) was then added slowly with stirring. The amount of reagent to be used depends upon the amount of free acid present. The solution must not be allowed to become alkaline. Boil a short time with stirring, and then remove the heat. The precipitate settles readily. Test the supernatant liquid with more of the phosphate. Filter hot through a Gooch crucible. Wash hot with 1 per cent. HNO_3 solution containing a trace of NH_4NO_3. 3 to 5 washings are sufficient, as the $BiPO_4$ tends to assume a colloidal form in dilute solutions. Dry at 120° and ignite 5 to 10 minutes before cooling and weighing. By this method Bi is readily separated from Cu, Cd, Ag and Hg. Means for separating it from Pb are discussed, but the authors do not quote analyses. Salkowski (*Ber.*, XXXVIII., 3943) also advocates the separation of Bi from the above and other metals by precipitation as phosphate in dilute HNO_3 solution.

Antimony — Electrolytic Separation from Tin. Fischer (*Zts. Anorg. Chem.*, XLII., 363). From sulphantimonites and sulphantimonates in a solution containing KCy, and excess of NaOH (2 to 4 gm.) Na_2S to saturation should be present. The current should not be over 0.9 volt.

Separating Arsenic from Antimony, etc. Cantoni and Chauterus (*Arch. Sci. Phys. Nat.*, XIX., 364). Adding methyl alcohol to an HCl solution of As_2O_3 and passing a current of air at ordinary temperatures causes the removal of As, as its methyl ester. Sb compounds are not removed by this treatment.

Tin in Alloys, Bronzes, etc. Levy (*Analyst*, XXX., 361). Volatilization in a current of dry Cl is the most rapid and satisfactory method. The alloy should be finely divided, or a skin of chloride forms on the surface of the metal, which causes irregular action. The alloy is placed in a 30 c.c. distillation flask, of which the side tube is bent at first upward, then down. The tube carrying the Cl through the neck extends well into the flask and is surrounded below the side tube with a plug of glass wool to prevent the carrying over of any material by spurting. The Cl used should be passed through a flask containing fuming HCl. To drive over the last traces of $SnCl_4$, remove the heat and allow the flask to cool, then add 10 c.c. HCl (after pushing the glass wool into the flask) and distil in the current of Cl. In the discussion Dr. Bevan mentioned that the most easily controllable mode of generating Cl was by dropping HCl onto $K_2Mn_2O_8$.

Gold — Precipitation as Metal. Jameson (*J. Am. Chem. Soc.*, XXVII., 1444). The slow subsidence of the precipitate obtained by use of $FeSO_4$ is well known. The author finds that by acidifying the solution with strong H_2SO_4 and adding a small stick of $NaNO_2$ (followed perhaps by another) the Au precipitates in the form of clots or nodules, which are easily separated by decantation.

Digitized by Google

Gold — Quantitative Separations. Jannasch and Mayer (*Ber.*, XXXVIII., 2129–2130). Au is precipitated quantitatively by hydrazin salts whether in neutral acid or alkaline solution. By this means Au can be quantitatively separated from practically all of the non-noble metals with the exception of Sn. The character of the precipitate varies with the metal present, though no contamination could be detected. Hydroxylamin also will separate Au, but the action is not so energetic, requiring heating to 80° or over.

From Pd in HCl solution, hydroxylamin separates Au perfectly. The Pd can be separated from the acid filtrate by hydrazin hydrochlorate similarly. Au can be separated in HCl solutions from Pt, Rh, Ir, Os and Ru. In the filtrates Pt and Rh could be separated quantitatively by adding excess of NaOH and hydrazin hydrochlorate and warming. The precipitation of Ir, Os and Ru by this means was imperfect.

Platinum and Iridium — Separation. Quennessen (*C. N.*, XCII., 29). Dissolve in a mixture of 1 vol. HNO_3 (Gr. 1.32) and 2 vols. HCl (Gr. 1.18). Evaporate to dryness and heat to expel HNO_3 completely. Dissolve in water and add metallic Mg, which precipitates both metals. Heat to dull red in a current of H. Remove Mg by washing with dilute H_2SO_4 (1 to 10) and then treat with dilute aqua regia, which dissolves Pt only. If ignition before treatment with H_2SO_4 is omitted, the separation is not effected, some Ir dissolving.

Columbium — Qualitative. Melikoff and Ellschaninoff (*J. Russ. Phys. Chem. Soc.*, XXXVII., 99). Potassium fluo-percolumbate in presence of a little H_2O_2 gives a yellow color with H_2SO_4. Or a concentrated solution of potassium percolumbate shows yellow when mixed with H_2SO_4 of 60 to 70 per cent. The reactions serve especially for the detection of Cb when present in Ta compounds.

Thoria — Separation from the Yttrium Cerium Group. Giles (*Chem. News*, XCII., 1 and 30). Dissolve the nitrates in one to two hundred times their weight of water, pass H_2S to reduce Ce, boil out H_2S keeping the volume of the solution up to its original dilution. Cool and add pure $PbCO_3$. Stir frequently for 12 hours, then filter. Th, Zr and Fe are completely precipitated. UO, Cr, and Al only partially. Ce, La, and other earths of the yttrium cerium group remain in solution.

Separation of Thorium. Neish (*J. Am. Chem. Soc.*, XXVI., 780). Meta-nitrobenzoic acid is a reagent which serves to precipitate Th completely. Two precipitations afford it absolutely free from Ce, La and Di. The reagent does not need to be completely free from isomers.

In monazite the mineral is decomposed by H_2SO_4, and the oxalates precipitated out in the usual manner. The oxalates are converted to oxides and dissolved in HNO_3. To this solution the meta-nitrobenzoic acid is added. $Th(C_6H_4.NO_2CO_2)_4$ precipitates. Dissolve in HNO_3 and reprecipitate. Ignite the moist precipitate and weigh ThO_2.

Thorium and Iron from Uranium. Jaunasch and Schilling (*J. Pr. Chem.*, LXXII., 26). Addition of hydroxylamine, heating, and then adding NH_4OH in excess precipitates Th and Fe clean from UOs in its compounds in two precipitations. If the filtrate contains only nitrate it may be evaporated and the residue ignited to determine U, or the NH_3 may be boiled out, the hydroxylamine destroyed by Br, and U separated by NH_4OH.

Digitized by Google

Tungsten in Ores. Desvergnes (*Stahl u. Eisen*, XXV., 221). Fuse 5 gm. of the ore with 5 gm. $CaCO_3$, and 2.5 gm. NaCl (Jean method). Boil the melt with water for an hour, add HCl and afterward some HNO_3. Evaporate to dryness — take up with dilute HCl, filter and treat repeatedly with boiling water containing HNO_3 and NH_4NO_3. Dissolve the residue with 20 c.c. H_2O and 10 c.c. NH_4OH. Pour the solution through the filter, dilute up to 100 c.c. and take 25 c.c. of the dilution — neutralize it with HNO_3 add HgO suspended in $Hg(NO_3)_2$ solution, and filter off the $HgWO_4$. Ignition of this precipitate affords WO_3.

Separation of Tungstic, Vanadic and Silicic Acids. Friedheim, Henderson and Pinagel (*Zts. Anorg. Chem.*, XLV., 396). Passing HCl gas over a mixture of the three acids heated to cherry red carries W and Vd into the receiver leaving SiO_2 behind. To the solution of W and Vd is added dilute H_2SO_4 with addition of a little SO_2 and the mixture evaporated. WO_3 separates, and in the solution Vd can be titrated with permanganate.

Zirconium—Qualitative. Ruer (*Zts. Anorg. Chem.*, XLVI., 456). Dissolve the precipitate produced by NH_4OH in HCl. Evaporate this solution to dryness over a water-bath, and then dissolve in a little water. The addition of conc. HCl drop by drop to this solution gives in the cold a precipitate of oxchloride — $ZrOCl_2.8H_2O$ which dissolves on warming but separates again in crystals on cooling.

Zirconium and Titanium in Minerals. Dittrich and Pohl (*Zts. Anorg. Chem.*, XLIII., 236). In the filtrate from SiO_2, precipitate with NH_4OH. Fuse the ignited precipitate with NaOH in a silver crucible. This will render Al, Mn and phosphate soluble in water. The residue is fused with $KHSO_4$, the melt dissolved in water, and H_2S passed in to reduce Fe. Then add tartaric acid in amount equivalent to thrice the weight of the oxides, render slightly alkaline with NH_4OH, and precipitate out Fe by $(NH_4)_2S$. After standing about 15 minutes filter and wash. To destroy the tartaric acid in the filtrate add persulphate and evaporate, add sulphuric acid and carry the evaporation down to fumes. Dissolve in water with a little HCl and precipitate Ti and Zr oxides with NH_4OH. Weigh the combined oxides and in a weighed portion determine Ti by Weller's colorimetric method (H_2O_2).

The ZrO_2 is estimated by difference.

Tellurous and Telluric Acid. Berg (*Bull. Soc. Chim.*, XXXIII., 1310). The material is weighed out in a porcelain boat, which is inserted in a combustion tube of hard glass, the end of which is turned downward at a right angle, the prolong delivering it into a U tube to which a second U tube is connected. Each U tube contains about 5 c.c. of water. The other end of the combustion tube is connected with an apparatus for the generation of HCl gas. On passing the gas and heating the tube at the boat to something under a red heat $TeCl_4$ volatilizes, and for the most part condenses in the upper part of the arm of the connecting U tube. When white vapors cease to be evolved from the substance the apparatus is disconnected and by a little manipulation the HCl in the first U tube can be brought in contact with the sublimate, and may then be transferred to a weighed porcelain crucible. The contents of the second U tube, which has served as a guard, may be used to

Digitized by Google

rinse out the end of the prolong, and the first U tube, the rinsings being added to the main portion. Add 5 c.c. HNO_3 and evaporate slowly on a sand bath. When it comes to dryness heat with great care. The temperature must be high enough to decompose the nitrate but not high enough to fuse the TeO_2 which would cause loss by volatilization. Eventually weigh the TeO_2. Of course the presence of substances volatilizable in HCl gas under these conditions, Hg, etc., is inadmissible.

Chlorides, Bromides and Iodides. Wentzki (*Zts. Angew. Chem.*, XVIII., 696). Hg_2Cl_2 when shaken with solution of bromide or iodide takes Br or I from the solution, a corresponding amount of Cl passing into the solution. Also Hg_2Br_2 when shaken with iodides affords Hg_2I_2, the Br passing into solution. If Cl and I are present, or Cl and Br, the solution is divided in halves. One half is precipitated direct with $AgNO_3$, giving a precipitate weighed as $AgCl + Ag$ (or $AgCl + AgBr$). The other half is shaken with excess of Hg_2Cl_2, filtered, and the filtrate precipitated with $AgNO_3$. The weight of the AgCl thus found compared with that of the mixed Ag halogen salts gives a basis for calculation of the amount of each halogen present. When Br and I are present the mode of operation is the same, except that Hg_2Br_2 is used instead of Hg_2Cl_2. If all three are present, the solution is divided into three equal parts. One is precipitated direct. The second is treated with Hg_2Cl_2 and then precipitated, the third with Hg_2Br_2, and then precipitated. From the weights of these precipitates the relative proportions of Cl, Br and I may be calculated.

Chlorates and Bromates. Scholtz (*Arch. Pharm.*, CCXLIII., 353). In the case of a chlorate, dissolve 0.2 to 0.3 gm.; of a bromate, 0.3 to 0.4 gm. in about 100 c.c. of water. Add 10 c.c. of HNO_3 (Gr. 1.2) and 10 c.c. of a 10 per cent. solution of $NaNO_2$. Allow to stand a short time at the temperature of the laboratory (5 minutes for a bromate, 10 to 15 minutes for a chlorate). Reduction occurs, and the chloride or bromide resulting can be titrated by Volhard's method — adding excess of standard $AgNO_3$ and titrating back with standard NH_4CNS, with $Fe_2(SO_4)_3$ indicator.

Chlorates, Bromates and Iodates. Jannasch and Jahn (*Ber.*, XXXVIII., 1576). The authors describe a series of experiments in which the aim was to reduce to the halide salts and determine the halogen in combination with Ag. Red fuming HNO_3 under pressure reduced all three to the halide combination, but the results were more conveniently obtained by the use of hydroxylamin sulphate with chlorate. The operation needs to be conducted in HNO_3 solution; with bromates and iodates an acid solution can be used, but for those it is preferably conducted in ammoniacal solution.

Sulphur in Iron and Steel. Pulsifer (*Chem. News*, XC., 230). A gravimetric method in which unusual speed is claimed. 2.5 gm. of the sample is wetted down in a 250 c.c. Jena beaker, and 50 cc.. of $HClO_3$ (gr. 1.12) with a few drops of HF are added. The vigorous reaction is over in less than a minute. Then 5 c.c. conc. HCl are added, and it is heated to boiling. Filter through a 7 m. filter paper, and wash two or three times with water. Add 20 c.c. conc. HCl to the filtrate, and boil the whole down to 10 c.c. Meantime place the filter in a nickel crucible, cover with Na_2O_2 and deflagrate with a strong flame, holding the cover down with the tongs. Dissolve in water and HCl and filter into the main

Digitized by Google

solution which thus brought up to about 100 c.c. is then ready for addition of $BaCl_2$.

Sulphur in Blendes and Zinc Products. Lunge and Stierlin (*Zts. Angew. Chem.*, XIX., 21).

The Watson-Lunge Method.— Sintering (not fusing) a mixture of the sulphide-bearing material with a known weight of $NaHCO_3$, leaching with water, and alkalimetrically determining the amount of Na_2CO_3 not converted to Na_2SO_4 by the reaction — is applicable to pyrites, but with blende and materials containing ZnS gives no satisfactory results. With addition of $KClO_3$ somewhat better results were obtained but in the case of high percentages of S (30 or over) complete oxidation was not effected unless some inert substance (S free Fe_2O_3) was added. Na_2CO_3 could not advantageously be substituted for $NaHCO_3$ as it renders the mass much less porous for lixiviation.

The charges should be:

	Ore, etc.	$NaHCO_3$	$KClO_3$	Fe_2O_3 (S free)
S. under 5 per cent.,	3.206 gm.	2 gm.	2 gm.	0
6 per cent. and over,	1.603 "	2 "	4 "	2 to 3 gm.
Raw blendes,	0.3206 "	2 "	2 "	2 "

Pulverize all the materials fine. Mix thoroughly in a small nickel crucible, apply the heat of burner with a flame 3 to 4 cm. high (tip 2–3 cm. from the crucible) for 30 minutes, then turn up the flame until the tip just touches the crucible. Keep it thus for twenty minutes, finally increase the flame until the bottom of the crucible is perceptibly at red heat — maintaining this for ten minutes more. Keep covered all the time. Cool, empty into a porcelain dish, boil up with water containing 25 c.c. of concentrated neutral solution of NaCl (free from $MgCl_2$) filter and wash with water (containing NaCl to hold back Fe_2O_3) until the washings are no longer alkaline, and titrate back with normal HCl, using methyl orange indicator. Some clouding due to dissolved Zn may appear at the end of the titration.

Sulphur in Coal. Brunck (*Zts. Angew. Chem.*, XVIII., 1560). Use 1 gm. of the pulverized coal with 2 gm. of a mixture of 2 parts Co_3O_4 with 1 part dry Na_2CO_3. Mix well and place in a porcelain or platinum boat. Insert the boat in a combustion tube connected with a supply of oxygen. Heat with a small flame until the mass begins to glow, when the heat should be removed, as the combustion will continue of itself, and can be controlled by regulating the supply of oxygen. In some cases it may be found advisable to pass the issuing gases through an HCl solution of Br succeeded by an NaOH solution of Br, but in most cases these are unnecessary. The mass is afterward dissolved in water, filtered, acidified and precipitated by $BaCl_2$. Black cobalt oxide (Co_3O_4) as supplied by dealers always contains S. The material for this purpose should be made by dissolving metallic Co in HNO_3, evaporating to dryness and decomposing the nitrate by heating to below red heat. The lower the temperature at which the nitrate is decomposed the more effective the material for this purpose.

Sulphur in Oils—liquid fuels. Goetzl (*Zts. Angew. Chem.*, XVIII., 1528). Weigh out 2 to 3 gm. of the oil in a capacious platinum crucible. Add about 4 c.c. fuming HNO_3 and cover with a watch glass. The first reaction is more or less vigorous. As it moderates move the crucible

Digitized by Google

about so as to gradually mix the contents. Let stand over night. Then warm up cautiously over a water-bath until the contents of the crucible has become a dried mass. Then fuse cautiously with 6 to 8 gm. of a mixture of 10 parts Na_2CO_3 with 2 of $NaNO_3$, mixing thoroughly. Add more of the fusion mixture if necessary to burn out all carbonaceous material. Finally dissolve in water and treat as usual, precipitating with $BaCl_2$, etc.

Maturin (*Zts. Angew. Chem.*, XVIII, 1766) criticizes the above as unsuitable with oils containing but little S, and also as less convenient than the Drehschmidt apparatus, which is constructed on the plan of the "referee" gas test.

Silicon in Steel (rapid process). Rubricius (*Stahl and Eisen*, XXV., 1012). Dissolve 5 gm. in 40 c.c. H_2SO_4 (1 : 2) in a moderately large beaker. After the first violent action is over, rinse down the sides with as little water as possible, and evaporate to fumes of SO_3. If the separated $FeSO_4$ protects some portions of the borings, add a little water or a few drops of HNO_3. After bringing to fumes, cool, dilute to 100 c.c. add HCl and boil — dilute to 200 c.c. filter, and wash with dilute HCl and hot water. Ignite and weigh.

Silicon in Irons. Thill (*Zts. Anal. Chem.*, XLIII., 552). Modification of Drown's method. The mixture for dissolving the sample is made as follows: 1 liter conc. H_2SO_4, 1 liter H_2O, 1 liter HNO_3 (Gr. 1.40), 1 liter NH_4Cl solution (240 gm. of the salt per liter).

50 to 70 c.c. of this mixture is used on 1 to 2 gm. of the sample in a half liter beaker, evaporated to fumes, etc.

Silica — Separation from Fluorine. Seemann (*Zts. Anal. Chem.*, XLIV., 343). The best method is with mercurammonium carbonate. To make the reagent add $(NH_4)_2CO_3$ to $HgCl_2$ solution until the precipitate first formed redissolves, or else digest freshly precipitated HgO with $(NH_4)_2CO_3$ solution.

Nearly neutralize the solution to be operated upon, leaving it slightly alkaline. Add the mercuric reagent and evaporate to dryness. Add water and more of the mercuric reagent, and evaporate again. Filter and wash. Ignition of the precipitate affords the SiO_2. In the filtrate the F may be determined by one of the various methods in use. Estimation as CaF_2 is not recommended.

Separate Estimation of Hydrofluoric and Sulphuric Acids. Ehrenfeld (*Chem. Ztg.*, XXIX., 440). Precipitate both together by $BaCl_2$ and weigh the combined Ba salts. Then digest the precipitate for an hour with standard solution of $CaCrO_4$ adding a little HCl, filter off $BaSO_4$ which remains insoluble. This may be weighed as a check.

In the filtrate adding excess of NH_4OH precipitates $BaCrO_4$ due to BaF_2 in the first precipitate weighed. Determine excess of $CaCrO_4$ by titration with KI and standard $Na_2S_2O_3$.

Fluorspar Analysis. Gregory (*Chem. News*, XCII., 184). Dry at 120° C.

Ignite 2 gm. at red heat until no further loss occurs. Loss = CO_2.

Treat 2 gm. (in platinum dish) repeatedly with HF, dry, ignite and weigh. After making correction for the alteration of $CaCO_3$ present to CaF_2, the loss = SiO_2.

Treat 2 gm. with conc. H_2SO_4 ignite and weigh. Correct the change

Digitized by Google

of weight for conversion of $CaCO_3$ to $CaSO_4$ and for loss of SiO_2 and then calculate CaF_2 from the $CaSO_4$ obtained.

Carbon dioxide—Indirect determination. Lutz and Tschischikow *J. Russ. Phys.-Chem. Soc.*, (XXXVI., 1274). $NaPO_3$, made by fusing microcosmic salt, is found to be most satisfactory for fusing with carbonates, natural or other, to determine CO_2 by loss of weight. The $NaPO_3$ fuses at a low temperature without loss of weight, even by long heating, and readily (in about 20 minutes) expels CO_2 from its combinations. It can also be used in a similar manner in nitrate analyses.

Absorbing Carbon Dioxide for Weighing. Schöler (*Chem. Ztg.*, XXIX., 569). Dissolving soap in the KOH solution used for absorbing causes a more rapid absorption on account of the viscosity imparted by the soap. The lather may work out of the potash bulbs arranged in the ordinary manner requiring a second potash solution, to which may be added a little $CaCl_2$. The author has devised a double KOH bulb adapted for this purpose.

Phosphorus in Phosphor Bronze. Dinan (*Chem. Centr.*, '05, I., 769). Dissolve 3 to 5 gm. of the sample in HNO_3 (1 : 1). The insoluble SnO_2 retains the P_2O_5. Dissolve the precipitate by boiling with a solution of 7 gm. $H_2C_2O_4$ crystals, and 7 gm. $(NH_4)_2C_2O_4$ crystals. The Sn is then deposited by the battery, and in the solution P_2O_5 may be estimated in the usual manner with MoO_3 mixture after destroying $H_2C_2O_4$.

Mineral Phosphates in Phosphatic Slags. Ledoux (*Congr. Chem. Liege*, 1905, 129). The phosphates in phosphatic slag are soluble in citric acid. Those in mineral phosphates are not. About 3 gm. of the pulverized sample is frequently shaken for half an hour with 50 c.c. of a 40 per cent. solution of $H_3C_6H_5O_7$. It is then filtered, thoroughly washed with hot water, and again treated for half an hour (paper and all) with 25 c.c. of the citric solution (strength as before). If mineral phosphate is present it can be extracted from the thoroughly washed residue by HNO_3. Determine by molybdate, etc.

Chili Saltpetre. Bensemann (*Zts. Angew. Chem.*, XVIII., 816 and 939). Dissolve 80 gm. of the sample in water and dilute to 1 liter.

I., *a* To 50 c.c. of this add HNO_3 and $AgNO_3$. Weight of the $AgCl \times 10.192$ gives per cent. NaCl.

b. Acidify 50 c.c. with HCl. Bring to a boil and precipitate with $BaCl_2$. Weight of $BaSO_4 \times 15.236$ gives per cent. Na_2SO_4.

II. To 100 c.c. of Solution I., add 16 gm. crystallized $H_2C_2O_4$ and evaporate to dryness. Wet down with water and dry again. Perform this operation five times. Then heat the dried mass in a platinum dish (Ni or Fe dish can be used) slowly up to red heat, until there is no more visible action (boiling, etc.). Keep it at red heat about 15 minutes, dissolve the mass in water, diluting to 250 c.c. = Solution II.

c. Dilute 125 c.c. of Solution II., acidify with HNO_3 and precipitate with $AgNO_3$. $AgCl \times 24.146$ gives per cent. $KClO_4$.

d. Titrate 100 c.c. of Solution II. with acid (1 c.c. = 0.080 SO_3, etc.). From the number of c.c. of acid required, deduct 0.2735 c.c. for every per cent. of NaCl, and 0.1305 c.c. for every per cent. $KClO_3$ (found later, III., *e*) and multiply the remainder by 3,375 to obtain per cent. of N_2O_5.

III. Apply Gilbert's method. Mix 20 gm. of the sample with pyrolusite and Na_2CO_3 solution, dry and fuse. Dissolve the mass in water, diluting to one liter.

Digitized by Google

e. In 200 c.c. of Solution III. determine Cl by acidifying with HNO_3 and precipitating with $AgNO_3$. Deduct AgCl as obtained I., *a*, and II., *c*. Multiply the remainder by 21.359, which gives per cent. $KClO_3$.

Nitric Acid — Gravimetric. Busch (*C. Rend.*, CXL., April, '05). Diphenylen-anilo-dihydro-triazol, in 10 per cent. solution, precipitates HNO_3 from its solutions when slightly acidified with H_2SO_4. At ordinary temperatures one part HNO_3 in 60,000 may be detected. HBr interferes by forming a difficultly soluble salt. It can be removed by expulsion with HCl. HI also interferes in the same manner — best removed by adding HIO_3 and boiling out I. HNO_2 and H_2CrO_2, which also interfere, can be disposed of by addition of hydrazine sulphate. The reagent is best added to the hot solution, which is then cooled down, finally with ice water, and then filtered (best in a Neubauer crucible), dried at 110° C. and weighed.

Nitrates and Nitrites. Meisenheimer and Heim (*Ber.*, XXXVIII., 3834). The weakly alkaline solution of the substance (containing 0.1 to 0.2 gm. of nitrite) is placed in a small flask (about 50 c.c. capacity), carrying a cork pierced with three holes. Two of the holes serve respectively for ingress and egress of a current of CO_2. The third carries a stopcock funnel tube for introduction of reagents. The exit tube for CO_2 dips under the surface of NaOH solution, delivering under an eudiometer tube. After filling the flask with CO_2, 10 to 15 c.c. of 5 per cent. KI solution is introduced by the funnel tube, followed by an equivalent amount of dilute HCl. The reaction occurring is: $HNO_2 + HI = NO + I + H_2O$. By warming gently — finally bringing to incipient boiling — the NO is driven into the eudiometer and measured. CO_2 is passed through during the whole operation. If HNO_3 is to be determined in the same sample, a second eudiometer tube is substituted for the first, and through the funnel tube is added 10 to 20 c.c. of strongly acidified (HCl) concentrated solution of $FeCl_2$, and the driving over of NO accomplished in the same manner as before. The reaction is: $HNO_3 + 3FeCl_2 + 3HCl = NO + 3FeCl_3 + 2H_2O$.

Cyanates — Volumetric. Cumming and Masson (*Chem. News*, XCIII., 5, and 17). (From *Proc. Soc. Chem., Ind.* of Victoria.) The method depends on the fact that cyanates are neutral to indicators, but when boiled with dilute mineral acids they neutralize a part of the same, NH_3 and CO_2 being formed, thus:

$$KCNO + 2HCl + H_2O = KCl + NH_4Cl + CO_2.$$

Hence, if one titrates a known volume of a solution of mixed carbonate and cyanate in the cold, using methyl orange or congo red indicator, the alkalinity measures the carbonate present. Then on adding a measured amount of standard acid, and boiling for a few minutes, the reaction indicated above occurs and on titrating back the cooled solution, the amount of acidity destroyed by decomposition of the cyanate gives the measure of the cyanate. The result may be checked up by adding to this solution a known excess of standard alkali, and after boiling out NH_3 titrating back again with acid.

The method can be used in presence of cyanide. In that case the alkalinity found is due to both cyanide and carbonate. The cyanide can be determined in the usual manner with $AgNO_3$, which should be essentially of the same strength with the standard acid. In these titrations the congo red is a very satisfactory indicator.

Digitized by Google

Oxygen in Copper. Archbutt (*Analyst*, XXX., 385). By heating the metal to redness in an atmosphere of H, and determining the loss in weight correct results were obtained. The metal does not need to be very finely subdivided to give correct results, but the larger the pieces the longer the operation lasts. Turnings required only one hour's heating; strips, $\frac{1}{16}$ to $\frac{1}{8}$ inch, about 2 hours; cubes, about $\frac{1}{4}$ inch, required 5 hours; a $\frac{1}{2}$-inch cylinder required nearly 10 hours.

Oxygen in Copper. Dickson (*Analyst*, XXX., 145). Fuse 10 gm. of pure Sn in a current of dry H. Then add 20 gm. of the sample of Cu (in one piece) and bring the mixture to fusion, also in a current of dry H. The H_2O formed is caught in a weighed drying tube and weighed.

Organic Nitrogen in Potable Waters. Campbell Brown (*J. Lond. Chem. Soc.*, LXXXVII., 1051). 200 c.c. is placed in a retort of copper or Jena glass, and KOH and $K_2Mn_2O_8$ solution added, as for Wanklyn's albumenoid ammonia process. The solution is distilled to dryness, and finally ignited for half an hour, the NH_3 being caught and determined by nesslerizing. After the ignition and cooling 250 c.c. of water are added, and the NH_3 remaining in the material is distilled over for determination. Free ammonia is determined in another portion and deducted.

Asphalt Testing. Donath and Margosches (*Chem. Ind.*, XXVII., 220). Distil 10 to 15 gm. of the sample. The distillate is always oily, wood pitch gives also water in the distillate which reacts strongly acid. Wood pitch scarcely colors CCl_4 on shaking with it.

If the distillate dissolves in absolute alcohol and glacial acetic, the presence of coal tar pitch may be asserted. Coal tar pitch also shows the presence of anthracene, detected by the Liebermann reaction. If the distillate does not completely dissolve in alcohol and acetic, lignite pitch, petroleum pitch, asphalt or a pitch from fat may be present.

Treat the original with alcoholic KOH and filter hot. If suint pitch is present a tolerably bulky precipitate of material containing cholesterin, etc., separates on cooling. If stearin pitch is present the separation does not occur until the alcohol has been driven off by heat and HCl added. For a closer examination, extract successively with petroleum ether, benzol and CS_2. If natural asphalt is the substance under examination, the residue is never black. If black or coal-like, lignite or petroleum pitch is present.

Asphalt Adulterations. Malenkovie (*Oesterr. Chem. Ztg.*, VIII., 123). The test with N/10 or 10 per cent. NaOH gives some useful indications. Boiling with formaldehyde gives no coloration with natural asphalt, but practically all substitutes give color to the solution. The action of alcohol and aceton is similar. Investigation is being made as to the value of the "Br. figure" and the "Acetyl figure" in these tests.

Estimation of Oil in Water from Condensing Engines. McFarlane and Mears (*Chem. News*, XCII., 108). If over 0.4 grain per gallon use 1 liter: if under 0.4 grain use 2 liters of the water. Make an Fe_2Cl_6 solution by dissolving 10 gm. Fe in 200 c.c. HCl; oxidize by HNO_3 and dilute to 1 liter. To 1 (or 2) liter of the water add 5 c.c. of the Fe_2Cl_6 solution. Heat to boiling, precipitate by NH_4OH, boil 2 minutes, filter through a paper previously extracted with ether, wash with hot water, dry and then extract with ether in a Soxhlet apparatus.

Digitized by Google

BOOK REVIEWS.

The Nature of Ore Deposits. By Dr. RICHARD BECK, Professor of Geology and Economic Geology, Freiberg Mining Academy. Translated and revised by WALTER HARVEY WEED, E.M., Geologist U. S. Geological Survey, etc., etc. New York, the Engineering and Mining Journal, 1905. Two volumes, 685 pp., 272 cuts, 1 map. Price, $8.00.

In this work Mr. Weed has made an important contribution to the literature of ore deposits. Though it is a translation, a considerable part of the matter relating to the general features of mineral veins has been written by the translator himself, who has also added further citations of examples of mineral deposits here and there throughout the two volumes.

The classification adopted by Mr. Weed is based on the origin, instead of the form, of ore deposits. In it the reader has the advantage of the latest results of research, both petrologic and chemical, and of the translator's own conclusions, as based on his long field experience and enthusiastic study of a subject whose literature within the past twenty years has become very large. Even the "practical miner," who is slow to change his views and usually recognizes only the form of the deposit, is becoming accustomed to the newer and more scientific classifications that have made their way since the days of Van Cotta, Köhler, and others. The looseness of opinion and statement respecting mineral deposits, that has been so common in the past amoi g those actually engaged in mining, is happily growing less. In this book both author and translator have avoided in large measure the "hard words" which abound in the works of some writers on this subject. They occur only infrequently in the body of the text, being used mostly in titles and subheads, and any intelligent miner will be able to read the book with profit. Perhaps it would have been well to give the geologist's definitions of some of the words not in everyday use among the mining fraternity, but the lack of them can hardly be rated as a shortcoming.

Following the genetic classification, the four main divisions of the work are entitled Magnetic Segregations, Bedded Ore Deposts, Epigenetic Deposits and Detrital Deposits. Under the first head are included chiefly the segregated deposits of iron and nickel. Bedded deposits comprise the deposits of direct sedimentary origin, together with those of the same or similar form which have resulted from impregnation of bedded rocks. All the deposits of this class are of iron and manganese.

By far the larger part of the work is occupied by a review of epigenetic deposits, or those formed later than the country rock. The word "epigenetic," in its general meaning, is usually taken as synonymous with metamorphic, but in its restricted geological sense includes all mineral veins and many bedded and impregnated deposits. The two chief subdivisions under this head are veins and epigenetic deposits in stratified rocks, exclusive of veins. To most readers, here will be found the most interesting part of the work. In it are comprised deposits of practically all of the important useful minerals.

The discussion of the nature and structural relations of veins, the

Digitized by Google

derivation and character of various vein fillings, action of vein-forming solutions on the wall-rock, influence of the country rock on the richness of veins and secondary alteration and enrichment, is very full and clear and is well illustrated. Possibly something more on the descriptive geometry of faults would not be amiss in the section on the location of faulted parts of veins. It is a little puzzling at first to find on p. 361, under the heading: "C. General Description of Mineral Veins," the note: "continued from p. 226." This seems to be a misprint. But Mr. Weed evidently has inserted here many pages of new matter, relating to vein filling, alteration of vein minerals and wall-rock, secondary enrichment and a summary of the various theories of the origin of veins. This forms a valuable addition to the book.

After the discussion on veins is the chapter on Epigenetic Deposits in Stratified Rocks, exclusive of veins. Under this head are included a number of important deposits, such as those of silver-lead, at Broken Hill, New South Wales, copper at Falun, Sweden and Ducktown, Tenn., pyrite at Huelva, Spain, gold at the Homestake mine, South Dakota, and on the Witwatersrand, and the zinc and lead of the Mississippi Valley. The work closes with the section on Detrital Deposits, chiefly of gold, tin and platinum, and some brief notes on the "Special Indications of Ore Deposits."

It might be thought that hardly enough prominence, or at least an imperfect perspective, has been given to some of the well-known mineral deposits; for example, the iron ranges in the northwest of the U. S. In the references to them, the deposits of the Marquette district seem to be unduly emphasized, considering the relatively large areas occupied by the hard and soft hematites of the other iron ranges of Michigan, Wisconsin and Minnesota. Also, some notes on the interesting pyrite deposits of Virginia and Canada, which have been of considerable commercial importance, might have been made. However, in treating such a large subject as ore-deposits, one of the greatest difficulties of an author is to keep the bulk of his subject matter within bounds.

Some of the cuts are on too small a scale; in a few of them the lettering and figures are indistinct and in places even illegible; *e. g.*, diagram, p. 22, figs. 31 to 34, p. 54, and fig. 177*a*, p. 327. In a few parts the typography is not unexceptionable.

The writer of this notice would suggest that a main division into four "parts," with chapter subdivisions, would have simplified somewhat the lettered and numbered headings of the sections, and probably would have permitted a better division into the two volumes than has been possible under the present arrangement.

There is a good index and detailed table of contents, with full lists of references to the literature of the subjects treated.

R. P.

Earth and Rock Excavation. A Practical Treatise. By CHARLES PRELINI, C. E. New York, D. Van Nostrand Co., 1905; 357 pp., 167 cuts. Price, $3.00.

The author of this work published in 1901 a book on a kindred subject — Tunneling. In the present treatise he has aimed to cover the entire field of excavation of earth and rock, including methods of work, estimation of costs, hand and machine tools, mechanical excavators and auxiliary

Digitized by Google

appliances, and apparatus for the transportation of excavated material. Taken together this makes a large subject and in a single volume of moderate size much detail in description cannot be expected.

There is a great deal that is good in the book, which is evidently the result of painstaking study and investigation. But we feel obliged to call attention to some of its shortcomings. Here and there we think the author has been unnecessarily brief. For example, the subject of rock excavation, including the composition and use of explosives and the methods of blasting (all of which under the title should form one of the two chief divisions of the book), occupies only 44 pages and is quite incomplete. Machine drills are disposed of in 8 pages, and are treated in an imperfect manner, the brief descriptions containing a number of inaccuracies. Thus, it is stated that, "in tunnel and mine work drills are frequently mounted on cast-iron columns"; "a drill tripod consists of a triangular block to which the legs are hinged"; "the valve is shaped like a spout and is inserted in a valve chest, within which it operates to and fro endwise, sliding on a loose mandril or bolt." Such imperfections are not infrequent. The brief reference to diamond drills is inadequate and in part incorrect, particularly the last paragraph on p. 61; and to say that, "with this simple machine holes can be bored to a depth of 300 feet," is misleading. It is stated, on p. 58, that all electric drills are constructed on the same principle. This is not so; and moreover, having described one of them, others equally well known should at least be mentioned by name. The description given of the Durkee drill is almost unintelligible without an illustration showing the longitudinal section.

Criticism of verbal infelicities of expression is disarmed by knowledge of the fact that English is not the mother tongue of the author, but errors and inaccuracies, such as are contained in the random quotations given above, might have been avoided by abstracting descriptions of mechanical details from the existing literature of the subject. It may be added that, in view of the small amount of space allotted to machine drills, the three-page description of the Brandt drill would better have been altogether omitted, since this machine is employed only in tunnels — a branch of rock excavation not touched on in the present volume.

The treatment of the subject of explosives and blasting is also unsatisfactory; as, for example, on pp. 85–86, in discussing the difference between explosion (by which the author evidently means "deflagration") and detonation. Among other things Mr. Prelini says: "the effects produced by explosion and by detonation differ; in explosion the effect is to raise up and force down the surrounding material, and in detonation the effect is to crush the material." Such statements will not be of great use to students and young engineers, for whom the book is specially intended. The subject of thawing of frozen dynamite is omitted entirely. In view of the importance of this matter some attention should be given to the methods and appliances by which the high explosives may be thawed in a proper and safe manner.

A number of errors in names, either typographical or in spelling, are to be noted, *e. g.*: on p. 68, Abel's name is given as Able; p. 70, lithofacter is printed for lithofracteur; p. 71, forsyte for forcite; p. 77, Blickford for Bickford, and Rizha for Rziha; p. 119, Barnhardt for Barnhart; p. 224, Bleickert for Bleichert; p. 243, Jenkins for Jenkin; p. 253, Shield for Shields.

Digitized by Google

While the subject matter, together with some of the illustrations, relating to rock excavation are rather imperfect, the part of the book devoted to the excavation of earth in its various branches is much more satisfactory. The mechanical appliances employed for excavation, and for the handling and transport of excavated material, are treated in chapters 8 to 18 inclusive at considerable length and generally with sufficient fullness. Capacities and rates of work, with approximate costs, are given in many cases. The chapters on traveling cranes, cantilever conveyers and overhead cable-ways, even so widely employed in connection with deep or large-scale excavation, are quite full, and the same is true of the descriptions (pp. 59–71) of the various forms of dirt cars used by contractors. It might be thought that the different types of plant for the excavation and back-filling of trenches, for sewers, water mains, etc., such as the Carson, Moore, Brown and Austin, would better have been grouped together, for purposes of comparison; and the decriptions should be accompanied by more effective illustrations, which are readily obtainable. They are referred to on pages so widely separated as 113, 211 and 230.

Chapter 20, on the Direction (or Organization) of Excavation Work, is a good one, though tabulations showing more clearly the relations between the work done by the various kinds of appliances would materially assist the reader in grasping the principles of a rather complex subject. Mr. Prelini does not lay sufficient stress on the character of the soil as affecting the rate and cost of work. The cohesion and specific gravity of the soil must be considered as well as the volume. Though this matter is referred to on pp. 42–44, it is not emphazised in connection with the discussion of costs elsewhere in the book. Nor does he show plainly the importance of the delays unavoidable in the operations of loosening, loading and transporting, which always influence costs. The title of chapter 2, on "Calculating Quantities and Cost of Earthwork" is somewhat misleading, as it consists entirely of a discussion of quantities. Upon the whole, however, the presentation of this part of the subject is good.

A shortcoming noticeable almost throughout the book is the lack of footnotes or references to the literature of the subjects treated. The reader who might desire to study further in some particular direction, finds but few hints as to where to look for sources of information. The index, also, could be greatly improved. Inaccuracies are noticeable, as well as omissions.

The book closes with an interesting chapter on the building of several important canals, such as the Suez, Manchester and Chicago Drainage Canals, and lastly a brief discussion of the great work now being resumed at Panama.

R. P.

The Economics of Mining. By T. A. RICKARD, W. R. INGALLS, H. C. HOOVER, R. G. BROWN and other specialists. Edited by T. A. RICKARD. New York, The Engineering and Mining Journal, 1905, pp. 421. Price, $2.00.

A few months ago we received with pleasure the book on "Pyrite Smelting," consisting chiefly of the discussion on that subject which for some time had been in progress in the *Engineering and Mining Journal.* The Economics of Mining is a somewhat similar compilation, comprising a number of articles, most of them in the shape of letters to the Editor,

Digitized by Google

which during the past two years have appeared in the same periodical. These papers are mainly on such subjects as: Costs of Mining, Valuation of Mines, Mining Finance and Investments, Ore-Reserves, etc.

Of late, all of these matters have been attracting considerable attention among members of the profession. Much of the material included in the book takes the form of a discussion, and the numerous editorial comments, from the pen of Mr. Rickard himself, have been influential in guiding the discussion and suggesting topics for further communications from correspondents.

A large amount of information of permanent value has been brought together in this book. Many of the articles are written with care, and benefit must result from the exposure and criticism of some hitherto widely accepted but erroneous methods of estimating ore-reserves, valuing mines and making estimates of costs of mining. Not least useful to engineers and managers are a series of articles containing detailed costs of operation (both mining and milling) at various mines in this country and abroad.

R. P.

A Laboratory Guide to the Study of Qualitative Analysis Based upon the Application of the Theory of Electrolytic Dissociation and the Law of Mass Action. By E. H. S. BAILEY and HAMILTON P. CADY, Professors in the University of Kansas. 5th edition. Philadelphia, P. Blakiston's Son & Co., 1905. Pp. x + 278. Price, $1.25.

Besides a theoretical introduction the book contains 228 pages, interleaved for notes, describing the qualitative tests for the identification and the methods for the separation of the common bases and acids.

The distinctive feature is the point of view, this is emphatically the physical chemical standpoint and the authors are to be congratulated no the concise and convincing explanations and examples of mass action hydrolysis, etc., to be found not only in the introduction but throughout the text. For these, if for nothing else, the book should be read by every teacher of qualitative analysis.

The weakness of the work lies in the lack of detailed directions about the conditions for complete precipitation, the deficiency of information in regard to the character, solubility and even the composition of precipitates For instance when potassium ferrocyanide in solution meets zinc ions $Zn_2Fe(CN)_6$ is not produced as is stated on page 188.

Qualitative analysis is valuable as giving practice in chemical reactions in cultivating accurate observation and should teach neat manipulation in order that it may be useful as a preparation for quantitative analysis. The book under consideration does not meet this demand although it is to be highly praised for the treatment from the ionization theory and will be useful in teaching qualitative analysis as part of a scientific education without regard to quantitative analysis. It is well printed and bound.

E. H. M.

Technical Methods of Ore Analysis. By ALBERT H. LOW. New York, Wiley & Sons, 1905. 8vo., pp. x + 273. Price, $3.00.

The book is divided into chapters on the following subjects: Apparatus, Electrolyses, Logarithms, Aluminum, Antimony, Arsenic, Barium,

Digitized by Google

Bismuth, Cadmium, Calcium Chlorine, Chromium, Copper, Iron, Lead, Magnesium, Manganese, Mercury, Molybdenum, Nickel and Cobalt, Phosphorus, Potassium and Sodium, Silica, Sulphur, Tin, Titanium, Tungsten, Uranium and Vanadium, Zinc, Combining Determinations, Boiler Water, Coal and Coke, Testing Crude Petroleum.

The work is of great value; it does not pretend to be a treatise on quantitative analysis, or to include the analysis of all inorganic materials; it is exactly what the title states, and, in the opinion of the reviewer, the subject of ore analysis is treated with completeness, care, accuracy and marked ability. The book covers a certain definite and very important field, giving the most recent and best American practice. It is not intended for a text-book but can be used to advantage by advanced students. It is written for practical analysts and will be appreciated by them, as it gives the methods in use in the author's laboratory. A few references are given, the principal authorities cited being Treadwell and Hillebrand. Several methods worked up by others are given, notably that of Ledoux & Co. for uranium and vanadium, and that of Waring for zinc by the ferrocyanide titration.

The appendix contains a new method for tin in ores by E. V. Pearce which is most welcome as offering, in all probability, a method which will take the place of the fire assay on low grade tin ores and so avoid the inevitable losses in both vanning and assay.

The book is well printed, of convienent size, and should be in the library of every individual or institution interested in analytical chemistry.

E. H. M.

Experimental Researches on the Constitution of Hydraulic Mortars. By HENRI LECHATELIER, translated by JOSEPH LATHROP MACK. New York, McGraw Publishing Co., 1905. 8vo, pp. ii + 132. Price, $2.00.

The book is essentially a translation of the thesis of LeChatelier, submitted in 1887.

It is divided as follows: Part I., "Plaster" (23 pages); Part II., "Silicates of Barium" (8 pages); Part III., "Cements and Hydraulic Limes" (96 pages), includes besides a historical review of the earlier work done in France; descriptions of synthetic studies of calcium silicates and aluminates; the results of microchemical study of cements; a discussion of the composition, the effect of calcination, the setting, the causes of destruction and the testing of cements.

It is an interesting record of experiments which contributed much to the present knowledge of the constitution of cement and should be read by those preparing to investigate this subject. No work on such a progressive subject, which is eighteen years old, can, in spite of the corrections as footnotes, be useful except for reference. As would be expected from the title no practical information in regard to the manufacture or the testing of cements is included.

E. H. M.

Digitized by Google

Manual of Chemical Analysis as applied to the assay of Fuels, Ores, Metals, Alloys, Salts and other mineral products. By EUGENE PROST, D.Sc., translated by J. J. CRUICKSHANK SMITH. New York, Van Nostrand & Co., 1904. 300 pages, large 8vo Price $4.50 net.

Part I. treats of the "Analysis of Fuels, Waters, Alkali Salts, Compounds of Calcium, Aluminium, Chromium, Iron, Manganese, Zinc, Nickel and Cobalt, Lead, Mercury, Bismuth, Cadmium, Copper, Gold and Silver, Arsenic, Antimony, Tin"; Part II., "Metals, Including Iron and Steel, Copper, Zinc, Lead. Aluminium, Tin, Nickel, Antimony"; Part III., "Alloys, such as Brass, Bronze Bearing Metals, Silver Bullion."

The analytical methods described are or have been standard methods within the past twenty years. Some are still excellent methods, all are well described and carefully selected, but many bring back recollections of the difficulties of methods long since forgotten. For instance, the decomposition of chromite by Dithuais flux, followed by the gravometric estimation of chromium has been superceded for many years in America by the sodium peroxide fusion followed by the volumetric method.

While the book contains nothing distinctly incorrect, and much valuable information, it is neither detailed enough for beginners nor thorough enough to satisfy chemists in particular lines.

The book may be useful to practical chemists, on account of the great range of inorganic products treated, when they need concise information on an analysis with which they are not familiar.

The translation is distinct, though the use of such terms as "chloride of soda" does not accord with present usage.

E. H. M.

The New Knowledge. A popular account of the new physics and the new chemistry in their relation to the new theory of matter. By ROBERT KENNEDY DUNCAN. New York, A. S. Barnes & Co., 1905. 8vo, pp. xvii + 263. Price, $2.00.

The book consists of an introduction and seven parts.

Part I., "Current Conceptions," treats of Matter, Ether, Energy, Compounds. Elements, Molecules, Atoms. The author uses extravagant English, thrown into sentences which may mean anything or nothing. His conception of a molecule is antique, to say the least, and shows no knowledge of modern chemistry. "A piece so small that if broken in two atoms are obtained," is not the view of a molecule held to-day by those who are informed on the theoretical chemistry of the twentieth century.

Part II., "The Periodic Law," is a good popular exposition of the periodic system, the aim being to present simple things in a startling manner. "For example, the silver-colored calcium is literally common as dirt; it lies on every street. Seventy-one per cent. of every barrel of lime is calcium and yet calcium is worth $14 a thimbleful."

The following sentences illustrate the "popular" character of the book: "What a phantasmagoric dance it is, this dance of the atoms!" (p. 15). "This periodic law of the atoms is God's alphabet of the universe" (p. 29). Although discussing the "new knowledge" in the light of the new chemistry, the author's ideas of chemistry are those of about 1885, and he seems totally ignorant of the physical chemistry of to-day; his statements lack true scientific precision.

Digitized by Google

Part III., "Gaseous Ions," is a distinct improvement on the preceding parts; the treatment of corpuscles is distinct and logical.

Part IV., "Natural Radio-Activity: A New Property of Matter." This, in the opinion of the reviewer, is the best portion of the book and is to be highly commended. The discussion of Becquerel's work and that of the Curies, of the different rays and emanations, is both concise and interesting.

Part V, "The Resolution of the Atom," covers modern alchemy, a flowery treatment of the breaking up or down of the elements of heavy atomic weight, interatomic energy, the electrical nature of matter, etc. The explanations of chemical affinity, etc., will either turn out to be wonderful predictions or ridiculous prognostications.

Part VI., "Inorganic Evolution," and Part VII., "The New Knowledge and Old Problems," is beyond the knowledge of the "skyptical chemist," so he refrains from either criticism or approval.

E. H. M.

Select Methods in Food Analysis. By HENRY LEFFMANN and WILLIAM BEAM. Second Edition, Revised and enlarged. Philadelphia, P. Blakiston's Son and Co. Small 8vo, pp. vi + 396. Price, $2.50 *net.*

The subject-matter of this work includes: general operations; poisonous metals, colors, and preservatives; carbohydrates; flour and leavening agents; fats and oils; milk and milk products; tea, coffee, and cocoa; condiments and spices; alcoholic beverages; flesh foods. Obviously so many important subjects can be discussed in a work of this size only by limiting the treatment to that required for some particular class of readers. This book is stated to be "for the practical worker in the détection of food adulteration" and is mainly a compilation of laboratory directions rather than a text-book or a condensed work of reference. It includes a large number of methods concisely described, but often with little if any attempt at explanation of underlying principles or discussion of sources of error and reliability of results. A very striking omission is that of the Babcock centrifugal method for the determination of fat in milk. Some very recent methods for the detection of artificial colors and other adulterations have been included in this edition. Definitions and typical analyses usually accompany the descriptions of methods and such of the United States standards of purity as had been adopted at the time of publication are also given. While not sufficiently complete or critical to replace the larger works on food analysis, this book will be useful to the analyst who wishes a condensed collection of methods for the chemical and microscopical examination of foods and food-adjuncts. A larger number of references more conveniently placed would add considerably to its value.

H. C. S.

Minerals in Rock Sections. Revised edition by LEA MCILVANE LUQUER. New York, D. Van Nostrand Company, 1905.

This text-book, the first edition of which appeared in 1898, is especially adapted to the beginner in work with the petrographic microscope and to the technical student whose aim is to apply the simpler methods of optical examination to the identification of rock constituents. The notable fea-

Digitized by Google

tures of the book as a laboratory guide are its brevity of statement, sacrificing detail to the essential points of dominant determinative value, and its concise tabulation of the minerals. This orderly arrangement of descriptive statements under separate headings, suggesting the series of tests or observations to be made, is of the greatest service in systematic laboratory practice.

In the new edition there are many modifications of statement and many additions of matter and illustration but the treatment is the same. Chapters I. and IV. have been rewritten. In the introductory text the changes involve a more complete topical treatment. Among the additions should be mentioned a much fuller discussion of the subject of refractive index at the close of which the Becke method is given in detail.

The paragraphs on interference colors together with the series of tests made by means of them or conclusions to be drawn from the modification of them are considerably extended. There are included methods of testing vibration directions of the faster and slower rays, of determining order of interference color, of measuring strength of double refraction, and of determining the thickness of a section and the unknown minerals in it by the use of a table of double refraction.

In Chapter IV., which is concerned with description of mineral species, there has been considerable enlargement and readjustment. This is most notable in the improved description of the feldspars and in the large number of cuts added to the individual descriptions, serving effectively either to simplify the discussions of optical behavior or to illustrate the appearance and occurrence in typical rock sections.

Several tables of much use in a guide for laboratory work are added including refraction tables and the Pirsson and Robinson diagram showing the relation between double refraction, interference colors and thickness. The scheme for optical determination is not materially changed in treatment but is rearranged and much more conveniently inserted for consultation while other portions of the book are in use.

The book has 141 pages of text, being 30 pages larger than the first edition. It is materially improved at many points while the characteristics that have made it so useful to the beginner and technical student are preserved.

The chief omissions from the book are due to the avowed purpose of the author. To give a brief discussion of the subject. It is not so exhaustive as Idding's translation of Rosenbusch, but is preferable to it for the inexperienced worker. In this respect it more nearly parallels the two later German texts by Reinisch and Weinschenk. It occupies a particular field in determinative mineralogy not reached by any other text in English.

C. P. B.

The Production of Aluminium and its Industrial Use. By ADOLPHE MINET. Translated, with additions, by LEONARD WALDO, S.D. (Harv.).

This small volume of 241 pages is divided into two parts, the production of aluminium and the properties, uses, working, and statistics regarding the metal. To this is added an appendix by the author, which is an effort to refute certain criticism on the German edition, and one by the translator on aluminium in the United States.

Digitized by Google

Part I. gives a description of the various chemical methods for the production of the metal which have been proposed, or actually put in operation. The object here seems to have been to make a complete survey of the field. The value of this portion is marred, however, by the fact that few references are given, and the processes which were at one time successful are not given the prominence which they should have.

The electrical methods of production are given forty-two pages, and of these thirty-five are devoted to Minet's own process, Heroult's being disposed of in eight, and Hall's in three. As is well known the latter two are the only processes which are in use to-day; it seems a pity that the author should have considered them of so little importance. The description of the Hall process would give one but a faint idea of what this really is.

Part II. is considerably better, the subject of alloys of aluminium is treated at some length, and the electrical and mechanical data give some useful information on this subject. Soldering of aluminium is filled with various receipts, but after reading this portion the reader is quite at a loss to know which is the best process to use, the idea of the whole book seeming to consist of bringing together as many patent specifications as possible, with few references and less criticism.

Notes by the translator on aluminium in the United States in the appendix hardly suffice to bring greater value to the book. A chance was given here for a good description of the Hall process, but was not taken advantage of.

We believe the book as a whole is a poor treatment of a subject which is of great importance at the present time.

S. T.

Hand Book of Metallurgy. By Dr. CARL SCHNABEL, Koenigl. Preuss. Oberbergrath, and Professor of Metallurgy, Clausthal. Translated by HENRY LOUIS, M.A., Professor of Mining at Armstrong College, Newcastle-upon-Tyne. Second edition, Volume 1: Copper, Lead, Silver and Gold. New York, The Macmillan Company, 1905. 1123 pp., 715 ills. Price, $6.50.

The German text of the first edition of this work in two volumes was published in 1894 and 1896. This translation of the second edition of Vol. I., covering "Copper, Lead, Silver and Gold," appeared in 1905, the original having been brought out in 1902. It is expected that the second volume of the new edition, on "Zinc, Tin, Nickel, Mercury" and the minor metals, will be issued in its English version during this year.

The object of the work, as stated in the translator's preface, is to give "a complete account of the metallurgical treatment of all the metals ordinarily employed (except iron), together with all the recent improvements in the art, while at the same time pointing out the scientific principles underlying each process and illustrating each by examples from practice."

An enormous amount of information is presented in this treatise and there is evidence throughout of much painstaking research. Of the 1090 pages of text, copper occupies 369, lead 208, silver 340 and gold 170 pages. The various processes are represented by examples of practice from all parts of the world. In most cases the relative importance of the

Digitized by Google

different methods of treatment is well observed in the amount of space devoted to the description of each, and generally also, the author has avoided the mistake of giving undue attention to processes which are now chiefly of historic interest, refraining from detailing minutely processes no longer of importance save as they illustrate the development of the art.

In making the translation no substantial alterations have been ventured upon by Professor Louis, though recent information relating to new or improved processes has in some cases been added.

While recognizing the value of the treatise as a whole, we think the subject matter could have been presented more clearly if it had been divided into chapters; say a primary division into four parts, covering respectively the subjects of copper, lead, silver and gold; and each part subdivided into chapters. For example, reference to the various topics under the head of copper would be facilitated by some such chapter grouping as the following: Properties and Ores of Copper; Classification and Application of the Various Methods of Copper Smelting; Roasting and Calcining Copper Ores; Copper Smelting Furnaces; Smelting of Raw Copper Ores; Smelting Calcined Copper Ores; Calcination of Copper Mattes, etc. Under the arrangement adopted in the book, it is not always easy to find specific information for which search may be made. The reader is apt at times to lose himself in trying to trace the relationship and application of the more complicated processes cited, some of which are obsolete or nearly so. It might be thought also that the fundamental processes have not always been sufficiently emphasized.

We venture to suggest that the operations of crushing and pulverizing the ores might with advantage have been brought together in a single chapter and there compared, instead of treating them separately in connection with a number of different metallurgical methods, as though each process must necessarily be preceded by crushing and pulverizing in some particular kind of apparatus. In some parts of the work this had led to a lack of conciseness. Thus, in the metallurgy of silver, a chapter might be devoted to "Preparation of the Ores" and so avoid repetition in the descriptions subsequently given of the amalgamation and leaching processes. The use of the Chilian mill is not monopolized by the Kröhnke process, nor are stamps employed only in preparing ore for pan amalgamation. The different varieties of pans also might well be taken up in close succession and their application and structural features compared. Again, the treatment of the amalgam from the various silver processes might better be discussed as a separate subject and not described under several different processes. Similar suggestions would apply to other portions of the metallurgy of silver, such as the operation of roasting.

We think that the cyanide process has hardly been treated with sufficient fullness, in view of its important place in gold metallurgy and the extensive literature existing on the subject. A greater amount of space is given to the chlorination process, notwithstanding that it has been so largely replaced by cyanidation. An outline of the chemistry of the cyanide process is well presented and the general description of the principal methods employed will be found satisfactory. Some of the recent developments in cyanide practice, however, are not noted; for example, crushing in cyanide solutions, the use of ammonia and its compounds in

Digitized by Google

connection with the cyaniding of cupriferous ores the regrinding of sands, etc. A discussion as to the conditions under which the cyanide process is best applicable, together with a summary of the possible causes of failure, would be desirable, also a concise comparison of the chlorination and cyanide process.

The metallurgy of silver is given in a very satisfactory manner, the main divisions of the subject being: The conversion of the silver into a silver-lead alloy (reference being made to the smelting of silver-bearing lead ores as described at length under "Metallurgy of Lead"); the production of silver amalgam and the production of a silver compound soluble in aqueous solutions. The older processes, such as the Pattinson and zinc desilverization, are described in much detail, as are also the methods of cupellation. Possibly undue prominence has been given to the Kröhnke amalgamation process, a relatively unimportant local process which might have been included under the general heading of barrel amalgamation.

Under "copper" it may be mentioned that the large output of this metal from the smelting establishments treating the product of the Lake Superior dressing works, would seem to demand more attention than the very brief notice (of less than one page) on p. 270.

The general index is rather imperfect and should be enlarged with more cross references for a work of this size, thus such important matters as "Stamp Mills," "Smelting," "Plate Amalgamation," "Lixiviation" or "Leaching," and "Precipitation" do not appear at all, and the only item indexed under "Cyanid Process" is the "Method for the Extraction of Silver."

Reference footnotes are frequently inserted, but a bibliography appended to each division of the work would be of great value to the student and to the general reader who may desire more detailed information upon any of the subjects treated.

The translator's work is well done and the book handsomely printed. Illustrations are liberally supplied throughout, many of them being dimensioned; though the scale on which they have been reproduced is not infrequently too small, so that the dimension figures are sometimes difficult to read.

R. P.

Digitized by Google

THE

SCHOOL OF MINES QUARTERLY.

VOL. XXVII. APRIL, 1906. No. 3.

ISOLATED PLANT ENGINEERING.

BY PUTNAM A. BATES.

To obtain the full advantages of an isolated plant, it is essential that each piece of apparatus installed shall be the most suitable for the conditions under which it will have to work and that the plant when considered as a whole will be capable of manipulation and operation in such manner as to produce a maximum efficiency at all times and require a minimum of labor for operation and maintenance.

To accomplish this the entire plant must be analyzed from the delivery of the fuel, to the supply of current at the switchboard. It is not sufficient to follow the pattern of some other plant which is supposed to be operating satisfactorily, and make the necessary changes in size of units to suit the load conditions.

A careful study must be made of the functions which it is intended that the plant shall perform and the type of plant which will be best suited to perform these duties in the most efficient and economical manner.

The first and most important question which must be decided is that of the type of prime mover to be employed.

Until very recent years the commercial limitations were such as to present, what may now be considered, but few types from which to select.

The plant in which the prime mover was other than the reciprocating steam engine was a distinctive exception, therefore few cared to give much consideration to the internal combustion engine using gas or oil or to the steam turbine.

Hence so far as the power producing apparatus in the plant was concerned, the questions which were at that time of prime impor-

Digitized by Google

tance, were whether the expansion in the steam engine should be single or compound, whether a condenser should be used, and what would be the most suitable pressure under which to operate.

This state of affairs does not exist to-day as the internal combustion engine has been brought forward as a prime mover and its improved economy in fuel consumption over that of the reciprocating steam engine, justifies its recognition and consideration.

For commercial use the internal combustion oil engine has not been developed in the same way that has the gas engine and except in the case of the small units and in a few special instances, its use has not thus far received the consideration which must be given the latter.

The lack of uniform angular velocity and the uncertainty in action and high maintenance cost were objections to the use of internal combustion engines for electrical purposes which recent developments have removed. Their inability to carry heavy overloads, however, together with the fact that their range of economical load is practically limited to between 50 per cent. load and full load, are defects which thus far have not been satisfactorily eliminated and which would be decided draw-backs in many plants. The question of speed regulation of these engines at light loads must also be considered when parallel operation is contemplated.

These difficulties may, perhaps, be best overcome by the installation of a storage battery plant to take the fluctuations in the load on the station, when direct currents are employed, but this is not always desirable or commercially practicable, and would usually add considerably in the first cost of the generating plant.

In sections of the country where cheap gas can be obtained the gas engine will show a much greater economy than any of its competitors, and recent improvements in gas producer and supply apparatus have brought the first cost of installation of gas plant equipments down to a point where it compares favorably with that of first-class steam plants using reciprocating engines.

The delay in the development and use of the gas engine has been largely due to the difficulty of making all elements of the engine and gas generating apparatus reliable in operation and to the absence of an efficient and inexpensive gas producing apparatus.

The introduction of the steam turbine has worked greater changes in the power plant design than any other item. It has

Digitized by Google

made it possible to take advantages of certain features of steam generation looking towards greater economy of power production which, due to inherent characteristics of the reciprocating type of steam engine, it was nearly or quite impossible to make use of before the advent of the steam turbine. It is true that since the coming of the steam turbine into the field of power generation, advances have been made in the art of reciprocating engine construction which make it possible to take advantage of those features to some extent.

The introduction of the steam turbine has carried with it the development of the super-heater and an effort on the part of the engineers to improve the efficiency of the furnace by providing more complete combustion of the gases. It has stimulated a higher development of condensing apparatus and it forced electrical manufacturers to design high speed generators, thus greatly reducing the floor space required per kilowatt capacity with the consequent saving in real estate, buildings and foundations, and making it possible to greatly increase the capacity of the generating unit over what appeared to be the practical limit for the reciprocating engine type.

Besides these direct developments which the steam turbine has brought about, it is also fair to place to its credit the renewed interest which it has created in the increase of power plant efficiency.

In determining upon the type of power plant equipment best suited to the requirements and conditions under consideration, many points must also be kept in mind, that at first thought might be considered as outside of the problem, but often prove to be the factors, which by proper treatment determine whether the plant will be a money saver or a money loser.

The reason for this condition is that most isolated plants, and many central stations are required to perform not only their primary function of producing and delivering power, electrical or other, but must in addition supply other needs of the buildings, communities, or town which they serve, and the efficiency with which these combined conditions are met, rather than the efficiency of the plant considered merely as a power producer, is the factor which often determines the value of the plant from a commercial standpoint.

Thus it is not sufficient to determine merely under certain conditions of load and environment, whether for example, a kilowatt

Digitized by Google

hour of electrical energy may be generated more economically by the use of water wheel, internal combustion engine or steam engine, and in the case of the last-named type, whether the plant shall run condensing or non-condensing, but, before deciding on this point, careful consideration must be given to the question whether, by the use of some particular type of apparatus, some other end may not be served which will add to the revenue of the plant or increase the saving which it is able to bring about, and at the same time accomplish its primary function with a reasonable degree of economy.

The problem of the subdivision of the equipment into the most suitable units is also a very important one and the manner in which it is solved frequently determines the usefulness of the plant from a commercial standpoint.

Many plants, which under different conditions would produce good results, are daily losing money for their owners or are shut down and represent an investment entirely wasted, simply because this question of the proper subdivision into units was lost sight of or ignored.

It is not easy to determine this point before hand, but, by a careful study of the conditions and a comparison with others of a similar nature, it is possible to predetermine the character of the work very closely.

Take, for example, a large office building, club house or hotel. A good method of predetermining the load conditions in such a structure is to draw up, in tabular form, a schedule of all the rooms and apparatus requiring current for light or power in the building, and opposite each set down the estimated amount of current required in or by it during each of the twenty-four hours or less that the plant will be required to operate. A curve plotted from the totals obtained in this manner will be of great assistancein choosing the size and number of the units to be installed.

If, however, it is possible, as is sometimes the case, to determine the conditions by actual observation or test, this should always be done, as, if properly done, it is much the more accurate method.

It frequently happens, particularly where the power plant is to be installed in and serve some building, the primary object of which is other than the housing of the power plant apparatus, that limitations of space must be met which greatly modify the con-

Digitized by Google

ditions and narrow the field from which to choose the apparatus to be installed.

This condition is frequently chargeable at the door of our friends, the architects, but the fact remains and the condition must be met in the best possible manner and with as little sacrifice to poorer economy as may be.

The comparatively small amount of space required by the high-speed reciprocating engine, which has of recent years attained a high state of development and is able to show very good economy and regulation, is a great help to the engineer in overcoming the difficulties brought about by cramped engine rooms and frequently makes it possible to solve what at first seemed a hopeless problem in a very satisfactory manner.

It sometimes happens that the conditions are such that the installation of a single large unit would result in the highest economy of operation, but even under these conditious it is seldom wise to make such an installation unless it can be safeguarded by a storage battery or some other auxiliary source of power, as the crippling of this equipment for even a short time, would usually result in a loss far in excess of the saving which the single large unit is able to show over the cost of operation of a plant equipped with two or more units. This is true, not only of the engine or generating unit, but also of the boilers or other primary source of energy, and to some extent of the auxiliary apparatus of the plant.

On the other hand a division into but two units, unless each is of sufficient capacity to carry the full load, is little if any better, as in the event of one unit having to be shut down the remaining one would rarely have sufficient capacity to carry the whole load, even for a few hours, unless the capacity of each unit is considerably in excess of one half the total required to carry the load, in which event both units must operate continuously under conditions of loading very unfavorably to high economy. The use of two units, each of which is capable of carrying the full load continuously, is usually to be recommended only where the load is nearly or quite constant, as it requires that one large unit should remain idle continually and under less favorable load conditions the resultant economy of operation would not be so good as might be obtained with a greater subdivision.

A division into three units of the same size and type, each having sufficient capacity to carry one half the full load or, into two

Digitized by Google

large and one small, or one large and two small units any two of which could, if necessary, carry the full load, makes an arrangement which in all but very large plants is usually productive of a high degree of economy together with a reasonable degree of immunity from shut down and comparatively low first cost.

In choosing the units the advantages, in the way of spare parts and repairs, which are to be gained by the use of as few different sizes and types as possible, must not be lost sight of, and where for sufficient reason it is deemed advisable to install units of different types, it should be determined beyond all reasonable doubt that these units will operate in conjunction in a satisfactory manner.

Without entering into the pros and cons of direct *vs.* alternating current, suffice it to say that the same general principles may and should be applied in the selection of the type of generator and of the voltage at which the current shall be generated.

Thus, in the case of a group of shop buildings already equipped with motors for electric drive, it would ordinarily be unwise to select electric generating apparatus producing current of a different nature or voltage from that with which the motors were built to operate, as the choice of such apparatus would entail a heavy investment in new motors and add greatly to the interest tax properly chargeable against the power plant.

As another example, consider the case of a large office building requiring electric current for lights and for elevator and ventilating fan motors. In such a building the load conditions are rather unfavorable in as much as continuous or nearly continuous service is usually required, while the peak of the load is high and of short duration, and during the balance of the twenty-four hours the load is comparatively light and very irregular.

These conditions would seem to indicate the advisability of installing a storage battery plant, but, unfortunately the space limitations are often such as to put this entirely out of the question or to make it impossible to arrange a suitable battery room.

Under these circumstances, it is well to consider the advisability of making use of the public electric service from the street mains as an auxiliary source from which to draw at times of very light load, making it possible to shut down the plant at such times, or in case of a break down.

In this way the first cost of the plant may be reduced by the elimination of a small unit which might otherwise be required to

Digitized by Google

carry the load during the night and a portion of the day, and by a reduction in the amount of spare apparatus which would otherwise be necessary to provide against accidental shut down.

In order, however, to take advantage of this means of saving, it is necessary to ascertain and comply with the rules and regulations with which the lighting company necessarily restricts its customers in the use of the current supplied by it.

It may be readily seen, therefore, that this one factor frequently determines the type of current and the voltage, at which the generators shall operate, aside from any consideration of the relative advantages of one system or voltage over another, in the abstract.

And so it goes through the entire plant. Each particular item must be considered from all sides, and the pros and cons carefully weighed before a decision is reached as to the use of any particular type of apparatus to meet certain requirements, or as to whether a sufficient saving will result from the use of some piece of apparatus to warrant the expense of installing it as a part of the plant.

It is the care and thoroughness with which these principles are applied which determine, largely, whether a plant will prove a credit to its designer or not.

In order to bring out more clearly the practical application of what has been said, to particular cases, let us consider that of an isolated power station for a manufacturing plant, consisting of several buildings spread over the greater portion of a city block and located about six or eight hundred feet from the river.

This plant consists of several machine shops for doing both heavy and light work, a forge shop, a pattern shop, a storage loft for patterns and an office building.

Power for the operation of machinery in the various shop buildings was originally supplied by two steam engines located at different points in the works, each supplied with steam from a single boiler near by, and each driving a long line of shafting by means of a belt.

In time these engines became worn out and were discarded and a number of electric motors were substituted for them, a semblance of individual drive being installed in some of the shops. Current for these motors and also for some lighting was obtained from the public service mains in the street, and distributed from a switchboard in one of the shop buildings.

Digitized by Google

The two boilers, however, were retained and kept in commission as the steam was needed for driving a couple of small air compressors in the boiler plate shop, a high pressure hydraulic pump used to furnish water under pressure for the operation of hydraulic tools in the forge shop, a steam hammer also in the forge shop, and for heating the various buildings.

This arrangement was obviously uneconomical, both in operating cost and in space occupied, and it was therefore decided to install a central power generating plant where all of the power required by the works could be economically generated, without occupying valuable space in the shops with boilers, feed pumps. coal piles or non-productive machinery.

The space allotted to the power plant building was approximately thirty-five feet wide by sixty feet deep running back from the street to one of the shop buildings. These, then, were the conditions, and the problem was how best to meet them to secure the greatest economy of operation, and the greatest return on the necessary investment.

The first question to be answered was with regard to the type of plant to be installed.

The high-pressure, steam-driven hydraulic pump, and, if necessary the steam-driven air-compressor, could be replaced by electrically-driven apparatus, but no suitable substitute for the steam-hammer has, as yet, been marketed, and no form of heating is so well suited to the conditions which prevail at these works as that using direct radiation from steam to hot water.

As the advantage gained by the operation of the steam-hammer, and the saving which could be accomplished during about six months of the year, by the use of exhaust steam for the heating purposes, far outweighed any possible saving in the cost of power production which internal combustion engines might perhaps be able to show in comparison with steam-driven apparatus, the latter type was chosen in preference to the former.

The next point to be decided was the total capacity required and the most advantageous subdivision into units.

In order to obtain as much information as possible which would serve as a guide to help in determining this question, careful observations were made of the current consumption at different times of the day and under different conditions, and of the size, number and character of the various motors and tools in the shops. A careful

Digitized by Google

study was also made of the coal, water and electric bills for the preceding five years, in order to ascertain as nearly as possible how the load conditions changed from month to month and year to year.

As a result of this analysis, it was decided to install three electric generating units, two of sixty, and the third of thirty kilowatts capacity, and a single steam-driven air-compressor, it being unnecessary to provide a reserve machine of this type as the temporary crippling of this machine would shut down only a small portion of the works and would not interfere in any way with the other portions.

The type of prime mover and the relative advantages of operation with or without condensers came up next for consideration. As has already been pointed out, the advantages to be gained in this instance, by the use of exhaust steam for heating purposes were very great and as the steam required for this, constituted a very considerable percentage of the total amount of exhaust steam from the engines, the increasing economy of power generation to be obtained by the use of a condenser, even if condensing water were cheaply available, would apply only during the warmer months of the year and would not, for that reason show a sufficient return on the additional investment to warrant the installation of an equipment of condensing apparatus.

The rather limited amount of floor space, and the desirability of not encroaching upon the second floor of the power plant building any more than was absolutely necessary, as this space could be used to advantage for manufacturing purposes, eliminated the horizontal low speed type of prime mover from consideration in connection with the electrical generating units required for this plant, more especially as the air compressor must necessarily be of the slow speed type of engine and no vertical machine of the proper capacity could be found.

A careful comparison of operating efficiency, first cost, floor space occupied and general suitability of the various types of high speed reciprocating engines and steam turbines, showed a very decided advantage in favor of the vertical compound reciprocating engine as applied to the conditions already mentioned.

Having reached this point in the solution of the problem in hand, the steam generating equipment may now be taken up for consideration, and the total capacity, and subdivision into units, the

Digitized by Google

type of boiler to be used, and the nature of the auxiliary apparatus required, decided upon.

The nature and the amount of the load has already been determined in connection with the choice of the engine units, and to determine the total boiler capacity required, it simply remains to ascertain the amount of steam which these engines will consume when furnishing the requisite power, as determined by the manufacturer's guarantees, and to add to this amount of steam which will be consumed by the steam-hammer. In this manner it was found that the three hundred horse-power in boiler capacity would be sufficient, the horse-power rating being based upon the well-recognized standard of 34½ pounds of water evaporated per hour from and at 212° F.

The steam boiler is a much more flexible unit than the steam engine or electric generator, it being possible to force it far beyond what would be a safe overload for a standard engine or dynamo, and to obtain a reasonably good efficiency together with the small amount of floor space and the desirability of reserving some space for future enlargement of the boiler plant lead to the choice of two boilers each of 150 horse-power set in a battery.

It still remained to determine the type of boiler best suited to the requirements.

The ability to make steam quickly together with the desirability of carrying a high pressure with as little risk as possible and of using super-heating steam, in order to obtain the best possible economy from the steam engine units and obtain the full advantages to be gained by the use of compound steam cylinders lead to the choice of inclined water tube boilers with four-inch drawn steel tubes and wrought steel headers, equipped with super-heaters also of the tubular type placed at the top of the boiler setting and between the first and second pass of the furnace gases.

A cross drum type of boiler with fourteen-foot tubes was used in order to make it possible to set the boilers across the building, which arrangement was the most economical of floor space and lent itself best to the steam-piping arrangement, and at the same time to remove and renew tubes as occasion should require.

Having reached this point it became possible to proceed with the design of a suitable building for housing the apparatus to be installed.

Digitized by Google

The building decided upon is a two-story brick and steel fireproof structure having the boiler and engine room on the first or ground floor, and a 100-ton steel coal bin on the second floor, the remaining portion of the floor being available for manufacturing or other purposes.

A steel plate smoke stack four feet in diameter and with its top 125 feet above the boiler room level, also rests upon the second floor and is connected with the flue openings of the two boilers by means of a steel plate flue and breechings.

Coal is delivered by means of a chute from the side-walk to a bucket-conveyor running from a pit in the first floor, into which the chute opens, to a point above the coal bin on the second floor. This conveyor is entirely enclosed and provided with a spout at the top by means of which the coal is deposited near the center of the bin. A motor on the second floor drives the conveyor by a belt.

The boilers are located in a room by themselves, the side wall of the setting being carried out to form a partition wall between the engine room and the boiler room. This arrangement necessitates the cleaning of one of the boilers from the engine room, but was necessary in order to obtain sufficient room for a possible future increase in boiler capacity.

The coal bin is located directly over the firing space in front of the boilers and has two pockets, from the bottom of each of which hoppers are carried down to a height of about five feet above the boiler room floor and terminates in valves.

Under these hoppers a small coal-charging car runs on rails set in the cement floor, and from this car the furnaces are supplied. This arrangement makes it unnecessary to carry any coal upon the floor of the boiler room and, therefore, possible to keep this portion of the plant in a neat and cleanly condition.

Owing to cramped space and the nature of the soil, which prevented excavating to any great depth, it was not possible to make any special provision for the removal of the ashes, even if the quantity of these were sufficient to warrant the necessary expense which would be involved in providing for this in any other way than by hand, through the ash pit doors.

The boilers are built for a working pressure of 200 pounds per square inch, although, for the present at least, but 150 pounds will be carried and are each equipped with a super-heater designed to

Digitized by Google

increase the temperature of the steam, before it leaves the boiler 100° F., above the temperature of saturated steam at the same pressure.

Economizers were not installed for the reason it was found that a sufficient amount of surplus exhaust steam would always be available for use in a feed-water-heater to maintain the temperature of the feed-water at about 200° F.

The feed-water-heater is of the open type consisting of a cast-iron shell with copper drip pans or trays at the top, over and through which the feed-water percolates, and a settling tank and filter at the bottom. A branch from the exhaust pipe connects with the feed-water-heater, and the steam enters through an oil separator and mingles with the cold water trickling over the trays. In this manner the entering steam gives up its latent heat to the incoming water, is condensed and unites with the water, and the resultant hot water descends to the settling tank below to be drawn out and forced into the boilers by the feed pumps.

No steam outlet is provided for the heater only such quantities of steam being drawn into it as are required to replace that previously condensed.

Two boiler feed pumps are installed, one being steam-driven and the other electrically driven.

The former is a duplex ram-pattern brass-fitted pump, having a normal capacity of about twelve gallons of water per minute, and is intended as a spare unit to be used in case of emergency or at times when steam is required, but the electric plant is shut down.

The other is a triplex plunger type pump, having a normal capacity of eighteen gallons per minute, driven through a train of gears by a three-horse-power variable speed motor. The controller of this motor is provided with both armature and field resistance from the motor field circuit and from one half to one quarter by introducing resistance in the armature circuit. The pump is also provided with a by-pass from the discharge to the suction, by the opening of which, the amount of water delivered by the pump may be still further reduced when necessary.

Although this pump was much more costly than a steam pump of the same capacity, its much higher economy of operation amply warranted the additional expenditure.

Steam is delivered into the boilers into a five-inch heater running across over the boilers and through the dividing wall into the

Digitized by Google

engine-room, where it enters a five-inch steam main from which the various steam-driven units are supplied.

This header and main are made up of steel pipe flared out at each end over the face of the flanges to the bolt circle, and the face finished off to receive copper gasket. This construction reduces the possibility of leaky joints to a minimum.

The steam main is carried on brackets along the wall near the ceiling.

The exhaust main consists of eight-inch pipe with screwed flange joints, and is carried along the side wall of the engine room directly under the steam main and up in one corner to a point above the roof. An oil separator is installed beyond the point where the last exhaust pipe enters the main.

The three generating sets are installed in a row along one wall, and on the other side of a central aisle is the air compressor, the electrically-driven boiler-feed pump, space for an additional electrical generating set and a controlling and distributing switchboard.

The air compressor has compound steam and two-stage air cylinders, and is equipped with a reheater between the steam cylinders, and an inter-cooler between the air cylinders.

Steam for each of the engines is taken from the top of the steam main by means of an elbow and a long radius bend, thus providing for expansion and contraction of the pipe and making steam separators on the engines unnecessary.

The generators are direct-current, 240-volt, compound wound machine. The primary reason for the choice of this current and voltage was that all of the motors installed throughout the works, were wound for that, and the use of it makes it possible to take advantage of the public service as an auxiliary should it ever prove desirable to do so.

The lighting is taken care of by means of a three-wire system, fed from a rotary balancer installed near the switchboard. This arrangement was considered preferable to the use of a 240-volt, two-wire lighting system for the reason that this higher voltage does not lend itself well to the operation of many of our higher power illuminants, such as the arc light, so useful in the economical lighting of large enclosures.

The switchboard consists of seven panels of marbleized slate mounted upon a single iron frame, and set three feet from the wall. There is a generator panel for each of the three dynamos, a total

Digitized by Google

output panel, an equalizer or balancer panel, and a lighting feeder and power feeder panel.

Each of the generator panels is equipped with a single lamp bracket, an ammeter, a field rheostat, a three-pole switch the middle pole of which performs the functions of an equalizer switch, and a double pole, double arm, laminated contact circuit breaker with carbon breaks.

Upon the total output panel are two single lamp brackets, a power ammeter, a light ammeter, a recording ammeter for the total current, one side being connected to the bus bars and the other left blank for possible future connection to the public service, a recording watt hour meter for registering the total amount of electrical energy generated, a double-pole power switch and two smaller double pole switches, one controlling the supply of current to the equalizer panel, and the other the circuit feeding the electrically-driven boiler-feed pump.

The equalizer panel is equipped with two single light brackets, an ammeter for indicating the amounts of current flowing in the neutral wire of the three-wire system and its direction, and a voltmeter for indicating the voltage on either side of this system — each of these instruments has the zero in the center of the scale and reads to the right and left — a voltmeter switch, the balancer field rheostat, a three-pole, double-throw switch for the control of the lighting supply of current to the lighting feeder panel, one side being connected to the bus bars and the other left blank for possible future connection to the public service, a switch and starting box for the control of the balancer and a double-pole circuit breaker. This circuit breaker is rather peculiar in that the actuating coil is connected to the neutral wire from the balancer, while the blades are connected to the positive and negative wires, respectively, of the three-wire system. By this arrangement an excessive unbalancing of the lighting circuits which would overload the balancer would trip the breaker and open the outside legs of the system, thus protecting the balancer from overloads without running the risk of an abnormal increase of potential of one side or the other of the system which would, to say the least, be detrimental to the life of the lamps.

Each of the feeder panels is equipped with two single lamp brackets, and a number of feeder switches from which feeders are run to various points through the works.

Digitized by Google

On top of the switchboard a large illuminated dial voltmeter and a potential indicator of the same size and type are mounted. These are connected to a voltmeter switch on one of the generator panels, and to the main bus bars respectfully.

From this switchboard the generation of the current and the distribution throughout the works is controlled.

A somewhat knotty problem was presented in connection with the air compressor.

As you know whenever air or any other gas is compressed heat is generated, and the greater the compression the higher the temperature to which the gas is raised. This is what occurs in the air cylinders of the air compressor, and unless this heat is removed, the temperature to which the cylinder walls will attain will be destructive. To overcome this it is customary to provide water jackets around the cylinders and, in large two-cylinder machi- inter-coolers as well.

The amount of water necessary to cool the air compressor of the machine in question was estimated at fifty gallons pe- nute. The only availably supply of water was from the city m- is and the cost of this amount from that source was too great to be considered.

To overcome this difficulty it was finally decided to install a cooling tower upon the roof through which the water could pass, after becoming heated in the jackets of the compressor, and be cooled and used again.

A small tank was placed on the second floor to which a water pipe terminating in a ball cock was run and in the engine room below, near the compressor, a small motor-driven rotary pump was installed. A water pipe was run from the tank to the suction inlet of the pump, and from the discharge outlet of the pump another pipe was run and connected to the inlets of the water jackets. From the jacket outlets a pipe was carried to the top of the cooling tower and from the collecting pan at the bottom down to the tank on the second floor.

A by-pass and waste pipe was also provided which make it possible to allow the water to run to waste when desired, as for example, when it becomes necessary to clean or repair any of the parts.

By this arrangement only sufficient water is drawn from the street mains to make up the loss by evaporation which is about five

Digitized by Google

per cent., and the cost of the necessary electrical energy is trifling compared with the saving accomplished.

The total investment necessary to accomplish this result was about equal to the cost of the water for one year if this water were allowed to run to waste after being used in the jackets.

In addressing you this evening, it has been my desire to outline to you a few of the actual conditions which consulting engineers have to meet in dealing with this particular problem which has been selected as our subject for this occasion. I have endeavored to give a clear exposition of the principles governing "isolated plant engineering" and to develop them in accordance with the best practice of the present time.

To treat the subject as comprehensively as possible I have confined myself to conclusions which are based on results obtained from actual conditions found in plants of the character referred to.

And in conclusion I may say, to those of you who contemplate having to deal with power plant design, that it is well to remember that with all the conditions which affect such plants you will seldom find two alike. You must, therefore, in each case make a complete analysis of the results to be accomplished, and a careful study of the means at your command.

Digitized by Google

GEOLOGY OF PIOCHE, NEVADA, AND VICINITY.

FRED J. PACK.

TABLE OF CONTENTS.

Page.
Introduction 285
Part I. — General Geology.
Geography 288
Stratigraphy 290
Distribution and Character of the Rocks 290
Sedimentary Rocks 290
Quartzite 290
Shale 291
Limestone 292
Age of the Sedimentaries 292
Igneous Rocks 296
The Yuba Dyke 296
Structure 300
Relation of the Structural Features to the Topography 305
Origin of the Pioche Mountains 306
The Highland District 308
Part II. — Petrography.
Igneous Rocks 310

INTRODUCTION.

During the early seventies Pioche was one of the busiest mining camps of the West. Its period of greatest activity began in 1870 and ended in 1876. Since then the mines have been idle except for a short time near the beginning of the nineties.

The opinion is generally held by those who are but slightly familiar with the district that its deposits have been practically exhausted, and that further efforts to develop them would be attended with complete failure. This impression is doubtless the result of the sudden shutting down of the mines in 1876, and the failure of an attempt to reopen them some fifteen years later.

Very little has been recorded concerning the geology, for the period of mining activity was so brief that interest soon died out, and to-day the camp is almost wholly forgotten.

Mr. Grove Karl Gilbert visited Pioche under the direction of the Wheeler Survey in 1871. He made some observations on the stratigraphic and economic features, and also gathered a number of fossils, but these were later destroyed by fire. His notes are general and give but a very brief outline of the geological conditions. (See Wheeler Survey, Preliminary Report, Exploration in Nevada and Arizona, War Department, 1871, p. 42.)

Digitized by Google

In 1872 Maj. J. W. Powell, also of the Wheeler Survey, made a brief study of the structural features. He worked out the relation of some of the ore bodies to the stratigraphy, and also to the faults. The results of his investigations are extremely valuable, as, indeed, many of the conditions which he observed are now inaccessible. (U. S. G. S. West of the 100th Meridian, Vol. III., pp. 243, 257–261.)

So far as can be learned Mr. R. W. Raymond, then United States Commissioner of Mining Statistics, was the first to study the district purely from the economic standpoint. He made a trip to Pioche in 1872, and has left on record only a few paragraphs as the result of his investigations. (Mineral Resources West of the Rocky Mountains, 1873, pp. 176–180.)

In 1885 Mr. C. D. Walcott, of the United States Geological Survey, made a rather extended trip through various parts of Nevada. He gave considerable attention to the Cambric section at Eureka, and later studied the Highland Range a few miles to the west of Pioche. He also made observations in the Pioche Mountains, and discovered, or at least described, a very fossiliferous horizon belonging to the Mid-Cambric, which he correlated with certain members in the Eureka section. He collected a fauna that had not previously been described. Mr. Walcott's report was the first that in any way aimed to give the details of the stratigraphy, indeed, his is practically the only statement relating thereto. (See U. S. G. S. Bulletin No. 30.)

Mr. J. E. Spurr, of the United States Geological Survey, while on a long trip through southern Nevada in 1899, visited Pioche and made a number of observations in the vicinity of the mines. As far as his conclusions are recorded he confirms the opinions of those who preceded him. He has given some additional notes concerning the Tertiary formations in Meadow Valley to the southward. (See U. S. G. S. Bulletin No. 208.)

Mr. R. W. Raymond has put on record considerable data concerning mine production. From this source the writer has largely drawn for the statistics contained in this article. (See Mineral Resources West of the Rocky Mountains, 1870–1876.)

A great many mining reports have been written on the various properties, but as they were never intended for the public their circulation has been very much limited.

Through the suggestion of Prof. James Furman Kemp the writer undertook the investigation of the Pioche region. We had well in

Digitized by Google

mind the fact that the district offers a wonderfully fine combination of problems in nearly every branch of geology. There are the ore deposits; the igneous rocks; the sedimentary strata; and the associated fossils beside the many complex structural features.

The writer took the field in the fall of 1905. Many of the old mines were found to be quite inaccessible, and consequently most of the information concerning underground formations, had to be obtained from reports, and from the few mines that could be entered. Since the necessary personal observations were impossible, the details of several of the deposits have been omitted. This is a source of regret, but at present it is unavoidable. The data concerning these formations have been selected with care. Indeed, in most cases they have been verified by observation. Four or five of the mines are still open, and these were studied in considerable detail.

Conditions are almost ideal for surface examination. There is practically no vegetation to conceal the outcrops; the formations all stand out boldly, and the atmosphere is so clear that one can see long distances.

In most cases the outcrops of the metalliferous deposits "weather out," and are thus left standing above the general level of the surface. One occurrence was noted that extended the full length of the claim with scarcely a break.

The larger structural features are worked out with great facility, faults, folds, rolls, fissures and the like are in abundance, but their frequency often involves complex problems.

Mining operations in the fossiliferous horizon aided greatly in the collection of a characteristic fauna.

The igneous dykes were the only formations whose outcrops are not easily followed. They occur largely in the quartzite and limestone, both of which withstand weathering very much more effectively than the dyke itself. Consequently the latter is usually covered with detritus from the other formations.

Subsequent to the first visit the largest part of three months was spent in the office and laboratory at Columbia University working up the field notes, and then a second trip was made to the district. This occurred in February, 1906, and covered a period of ten days. The examinations made during this visit were for the purpose of confirming previous observations, and for settling questions that had arisen during the office and laboratory work in the east.

Digitized by Google

It is the aim of the writer in the present article to give a fairly complete account of the geology of the Pioche region. The detailed structure of all the ore bodies cannot be discussed as fully as desired, but sufficient information is at hand for general purposes.

The most courteous treatment has been extended by every one to whom I have applied for assistance in the prosecution of this work. While it is quite impossible for me to thank every one who has assisted me, yet I desire to mention Mr. E. P. Gordon and Mr. Ed. Freudenthal for general assistance in the field; Mr. William Lloyd and Mr. J. R. Cook for freedom in their mines and for data placed at my disposal; Mr. J. B. Wheeler for information concerning the old milling processes; the Nevada-Utah Mining & Reduction Company for a surface map of the district, and for other courtesies; and Mr. F. W. Dickle for his many efforts to make my undertaking a pleasant one.

To Professor James Furman Kemp the existence of the present paper is largely due. From the outset I have profited by his cordial advice and kindly criticism. I am also greatly indebted to Professor Amadeus W. Grabau for suggestions throughout the office and laboratory work, especially in connection with the stratigraphic and paleontologic features. Dr. Chas. P. Berkey has given every possible assistance in the petrographic work.

PART I. GENERAL GEOLOGY.

Geography.

Pioche, the center of the Ely Mining District, is situated in Lincoln County, Nevada, near the Utah Line. It is 325 miles southwest of Salt Lake City, and 28 miles north of Caliente, on the San Pedro, Los Angeles, and Salt Lake Railroad. Panaca, a Mormon village, is situated 12 miles to the south in Meadow Valley.

Several years ago a roadbed was made into Pioche, but the rails were never laid. It is understood that the railroad company has stated its willingness to complete this connection just as soon as the production of the district warrants it.

It is a well known fact that the Basin Ranges have a strictly north and south trend. This is so rigidly true that a relief map of the Great Basin looks not unlike an army of caterpillars headed in

Digitized by Google

Digitized by Google

FIG. 1. Tertiary deposits near Panaca, in Meadow Valley, twelve miles south of Pioche.

FIG. 2. The town of Pioche. The mines may be seen in the distance. (Looking south-west.)

Digitized by Google

a common direction. Southeastern Nevada, although just outside the Great Basin, is no exception.

Pioche is situated in a small range of hills extending east and west between Duck Valley on the north and Meadow Valley on the south. The trend of these hills is practically the only exception in southeastern Nevada.

Duck Valley is a broad typical desert valley. There are no canyons and the hills are rounded and rolling. The valley floor is covered by Quaternary wash.

Meadow Valley in its northern parts is likewise broad and flat. To the south it becomes gradually deeper and narrower. Twenty-five miles below Pioche and a short distance above Caliente, it becomes a true box canyon, with nearly vertical rhyolite walls rising on either side for several hundred feet.

During early Tertiary times this valley was converted into a lake through the damming up of its waters by great volcanic outpourings in its southern parts. Several hundred feet of Pliocene beds were deposited in the vicinity of Panaca and southward. Since then the great dam of igneous rock has been cut through, and a large part of the Pliocene beds has been removed. Vestiges of these deposits remain high up on the hill sides, and occasionally a circumdenudated mass still occurs in the valley below. (Plate 1, Fig. 1).

The Pioche Range, as it is called, is approximately 15 miles long by 1 mile wide. Its mean trend is about sixty-five degrees west of north. Mt. Ely with an elevation of 7,150 feet is the highest point.

The town of Pioche is situated in a depression of the northern slopes of the range, and about midway between its extremities. According to official survey it is a little less than 6,000 feet above sea level. The hills as a whole are practically one thousand feet higher than the town.

During the early days of active mining the camp had a reported population of nearly ten thousand, while to-day it has scarcely more than three hundred. For a mining camp it is exceptionally clean and attractive. Locust trees planted thirty years ago still survive and give the place a very homelike appearance. (Plate 1, fig. 2.)

The general aspect of the country is somewhat rounded. Even the heavy grades and precipitous inclines show evidence of long erosion. The slopes on the south side of the range are more

Digitized by Google

gentle than on the north. This is especially true in the western half where a fault escarpment marks the northern face.

The surrounding country is extremely dry and desolate. No streams flow from these mountains. A scanty growth of desert sage and scrub cedars comprises the vegetation. Pioche gets its water supply from a spring seven miles to the southwest in the Highland Range. The rainfall is slight and the winters are mild.

STRATIGRAPHY.

Distribution and Character of Rocks.

The accompanying map is designed to give a fairly correct representation of the areal distribution of the formations comprising the Pioche district, yet strict accuracy is by no means claimed for it. The only available map of the district is a topographical reconnaissance sheet based on the notes of the Powell and Wheeler surveys. In working out some of the larger features this was of service, but in detailed examinations it proved entirely inadequate. The writer has been forced to rely largely upon mining maps in determining the geographical distribution of the various formations.

The Pioche Mountains consist of a single anticlinal fold with its axis extending east and west in marked contrast to the general trend of the mountains of the region. The anticline has suffered greatly through faulting and erosion, so that now the various members comprising it are well exposed.

The best sections of the sedimentary formations are to be seen in the western half of those mountains and the mines also are here situated.

The strata comprising the anticline consist of quartzite, shale and limestone. When these formations are projected on a map the shale and limestone are seen to form concentric areas around the core of quartzite. The shale which is superjacent to the core is cut out in a few places by faulting, so that the quartzite comes into direct contact with the still higher limestone. This is the case near Pioche on the north side of the fold.

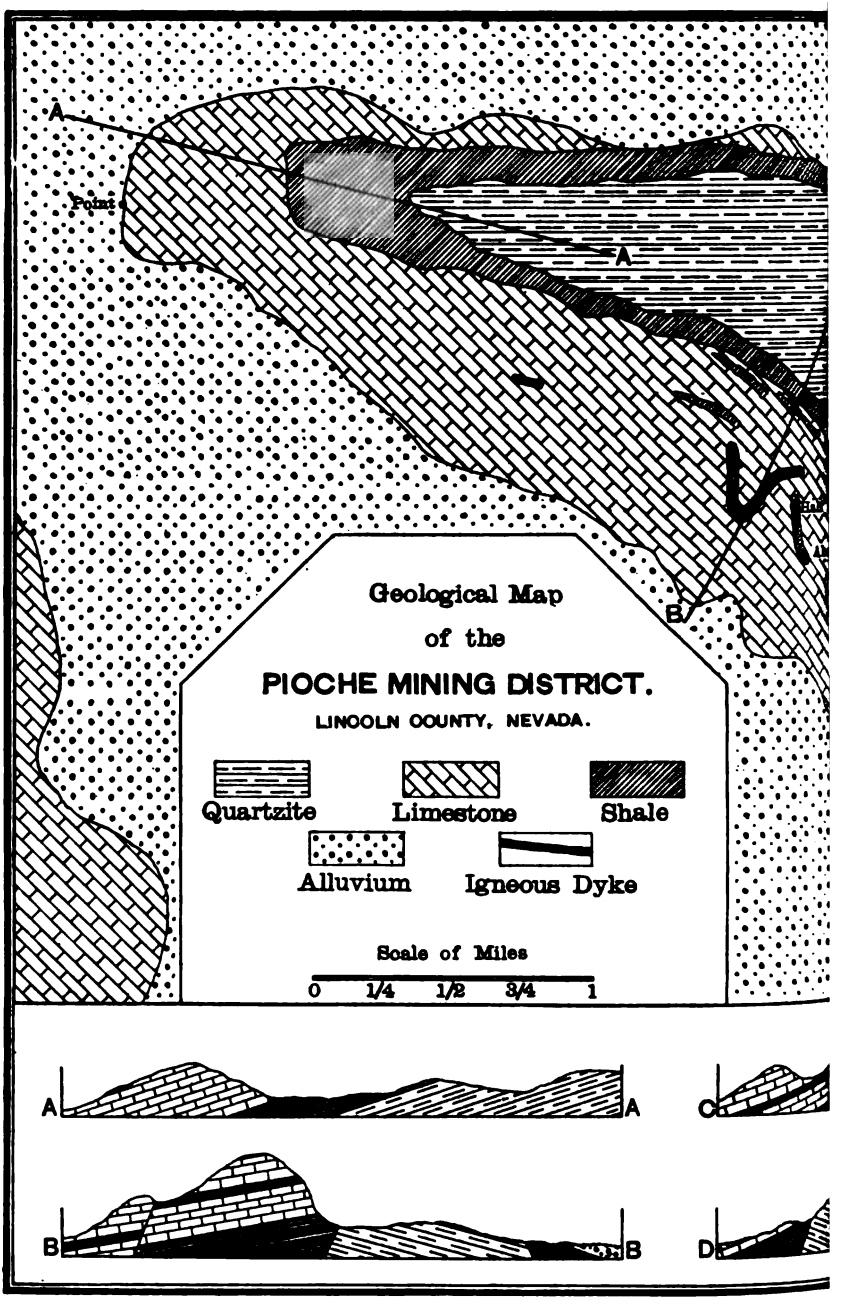
Sedimentary Rocks.

Quartzite.

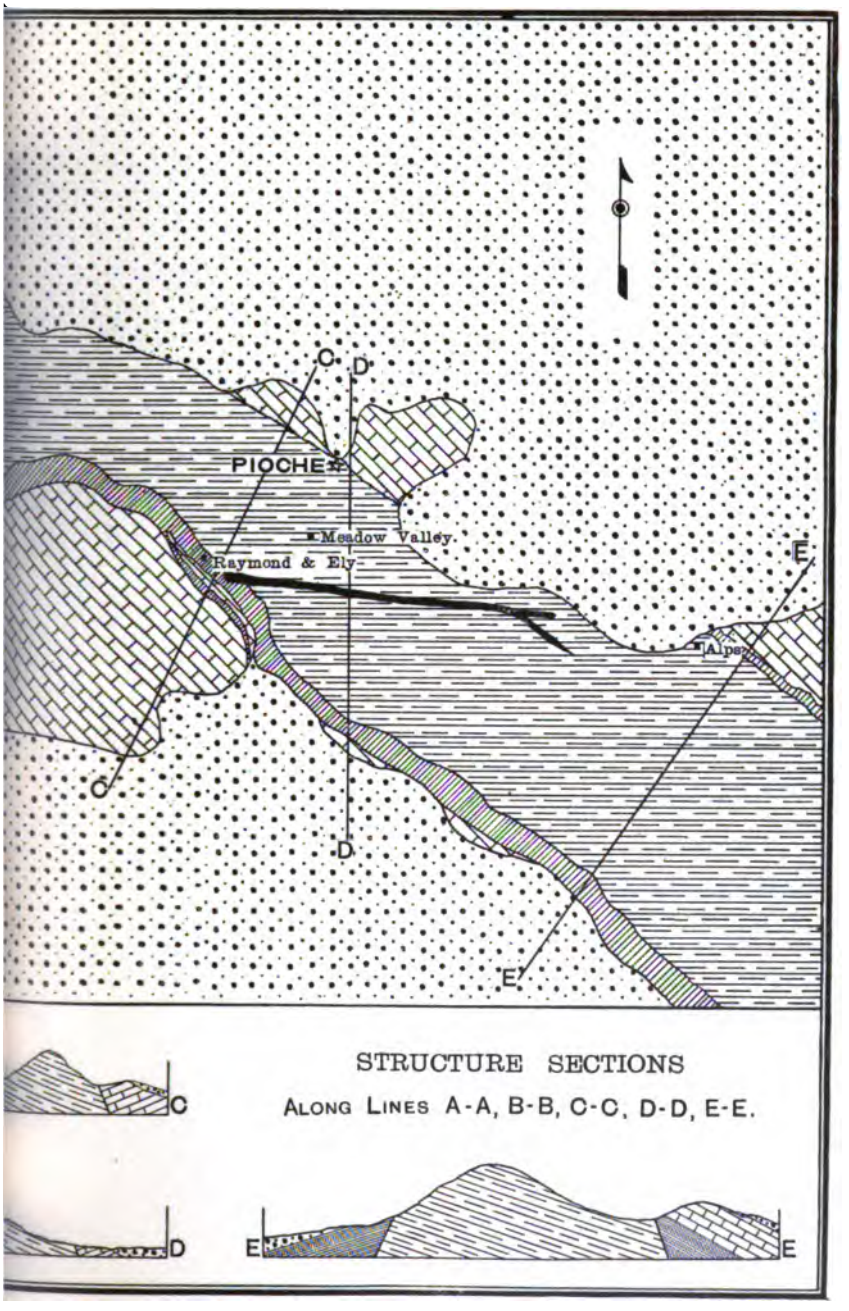
The quartzite is the lowest formation known and comprises the central outcrop throughout the greater part of the anticlinal ex-

Digitized by Google

Digitized by Google



Digitized by Google



Digitized by Google

Digitized by Google

Digitized by Google

FIG. 1. The Pioche Mountains. (Looking nearly due east.)

FIG. 2. The Half-moon mine. The dump shown shown in the upper right hand corner affords great quantities of mid-Cambric fossils.

Digitized by Google

posure. It has been thrust up between the side members and is, therefore, separated from them on either side by a fault plane.

From Pioche eastward for about two miles it forms the highest topographical features. Both to the east and to the west its altitude gradually becomes subordinate to that of the limestone. This condition is partly explained by reason of the fact that the thrust movement reached its maximum in the vicinity of the Pioche and decreased in both directions.

At the west the southern limestone member forms the central ridge of the range, while at the east this is true of the northern limestone member. The quartzite, although forming the axis of the anticline, does not form the axis of the mountains except for about two miles in the vicinity of Pioche. The two axes diverge from one another with an angle of probably five degrees.

The original bedding planes in the quartzite are largely destroyed, but near Pioche one can determine that the dip is practically fifteen degrees to the north, while elsewhere it varies greatly both in direction and amount. Although in its extreme western extension its contact with the superjacent shales could not be observed, yet there appears to be no fault between them, as they both dip to the west at the same angle.

The quartzite is very compact and massive, and ranges in color from a deep red on the surface to an almost pure white in depth. It is everywhere highly fractured and faulted and, therefore, weathers into sharp and precipitous forms.

Shale.

Superjacent to the quartzite is a layer of shale of varying thickness. It fringes the quartzite on all sides, except for a short distance at the north, where it has been cut out by faulting. In the greater number of its exposures this shale formation retains its original anticlinal inclination. In other words, it dips away from the center in all directions; at the south it dips to the south, at the west to the west, at the north to the north. This regularity has been destroyed in a few places, so that the beds now dip in quite unexpected directions.

In its typical condition the shale may be described as argillaceous. At a few points it has been altered into a fairly good mica schist. This is true in the vicinity of the Raymond and Ely property from which it has been quarried for flagging and building

Digitized by Google

purposes. It generally occurs as a finely laminated deposit, which when worked breaks along the bedding into thin slabs.

There are two of these shale members; one immediately overlying the quartzite, and the other several hundred feet higher. The second is much thinner than the first, and is much more limited in its distribution. It is best exposed two miles west of Pioche at the Half Moon mine. The general distribution of both shale formations is shown on the accompanying map.

Limestone.

The limestone forms the upper member of the anticline, and is, therefore, situated outside both the shale and the quartzite. It comprises the chief topographic features west of Pioche. In most cases it dips away from the anticlinal core, but in the two hills immediately east of Pioche it dips toward the quartzite.

There are but few traces of the original bedding planes remaining. The whole formation is exceedingly massive and in some places quite silicious. In fact interbedded seams of sandy calcareous shale are not uncommon, but they are very irregular and do not extend over wide areas.

It is at some places divisible into irregular masses (for they can hardly be called beds) of darker and lighter colored limestone. This condition is by no means sufficiently uniform to be useful in marking horizons, and is not, therefore, considered in discussing the stratigraphical position of the various members.

The limestone weathers into rounded masses, which form striking contrasts with the sharp peaks of the quartzite. It is extremely hard and rings under the hammer much the same as an ordinary quartzite.

According to the nomenclature proposed by Professor Grabau the quartzite is a metamorphosed silicarenyte; the shale is mostly an agilutyte, and the limestone is largely a calcarenyte with occassional beds of calcilutyte.

Age of the Sedimentary Rocks.

As far back as 1885 Mr. C. D. Walcott visited the Pioche region and correlated the formations with others in the Highland Range which he referred to the Cambric. He also correlated certain horizons here with the supposed Mid-Cambric of Mt. Stephen (*Am. Jour. Sci.*, 3d ser., Vol. 35, p. 161), and showed that much of

Digitized by Google

the fauna occurring at the latter place is identical with that of the Highland Range and Pioche Range.

Mr. Walcott used the Olenellus and Dikellocephalus zones as a basis for his correlation. He found between these horizons, which are widely separated in Nevada, a large fauna which he decided was approximately equivalent to the Paradoxides or Mid-Cambric zone of the east. He, therefore, has described this new fauna as belonging to the Mid-Cambric horizon.

Dr. G. F. Matthew does not concur with Mr. Walcott in this opinion but thinks that the Mt. Stephen fauna is Upper Cambric (*Trans. Roy. Soc. Can.*, 2d ser., vol. 5, sec. 4, p. 39), and would, therefore, argue that the equivalent horizons in Nevada also belong to the same age. He gives a table showing the genera occurring at Mt. Stephen, and also the horizons where related species and genera are found, which according to his arrangement nearly all belong to the Upper Cambric and some even higher.

Dr. Matthew has also advanced the idea in a later paper that the Olenellus fauna is not Lower Cambric, but that its proper place is above the Paradoxides zone. He would, therefore, have it appear that practically the entire sections at Eureka, Highland Range, and Pioche belong to the Upper Cambric, and that the Protolenus and Paradoxides zones are probably present below the Olenellus, but that they exhibit no faunas in these regions. (*Ibid.*, p. 69.)

There appears, however, to be little room for doubt that the Olenellus zone is properly placed below the Paradoxides zone, and well within the Lower Cambric. This opinion is held by such high authorities as Walcott (*Am. Jour. Sci.*, 3d ser., vol. 37, p. 374) and Brögger (*Aftrykur Geol. Foren. i Stockh. Forhan*, No. 101, Bd. 8, 1886, pp. 182–213) and is generally concurred in by all paleontologists.

We do not feel quite so sure, however, that the supposed Mid-Cambric fauna of Nevada and Mt. Stephen are equivalent to the eastern Paradoxides fauna, although this view is supported by Walcott and Brögger. The fact that this new fauna stands midway between the Olenellus and Dikellocephalus zones argues that it is likely Mid-Cambric. Walcott has also shown that many of the forms associated with this new fauna are elsewhere of this age.

The question then as to the exact horizon of many of the Pioche formations is not wholly settled. Years ago Mr. Walcott studied

Digitized by Google

this matter th extreme care, and has not seen fit to change his opinion by reason of his subsequent investigations. Several new species have been found by the writer, but none of them give any definite clue to the situation. In order to put this matter beyond question other districts must be studied and a wider fauna obtained.

In the present paper we shall hold with Mr. Walcott that the fauna represented in the upper shale member in the Pioche Mountains belongs to the Mid-Cambric horizon.

Faulting has so disturbed the strata comprising the Pioche anticline that a continuous section cannot be obtained. The quartzite has been thrust up between the flanking members for a distance estimated at fully 1,000 feet. Elsewhere it is not exposed on the surface, except at points several miles to the east of Pioche. Mining operations have shown that it is conformably overlain by alternating beds of shale and shaly quartzite. That is, it passes into superjacent shales through a series of thin transitional beds, which vary greatly in texture and thickness even in short distances.

The thickness of this quartzite formation can hardly be approximated. The Raymond and Ely Mining Company has sunk its works into it for 1,500 feet, and the bottom of the shaft is still within it. We shall, therefore, place the thickness at 1,500 feet, but it is likely very much greater.

Whether any fossils were encountered in passing through the transitional shaly beds has not been recorded, but five or six miles to the eastward at the same horizon a typical Olenellus fauna has been found. This marks the Lower Cambric horizon.

Above the quartzite is some 400 feet of argillaceous shale, which in the immediate vicinity of Pioche has been altered into a fairly typical mica schist. No traces of fossils occur, except near the upper part, where there are a few fragments of Zacanthoides.

Superjacent to the shale at Pioche is about 300 feet of massive silicious limestone, which is apparently unfossiliferous. This bed is conformable with the shale below. Its upper limit marks the crest of the hills. Two miles west of Pioche and just beyond Mt. Ely this limestone is fully 600 feet thick, and perhaps much greater, as the base is not revealed.

At the top it passes conformably into a bed of shale which varies greatly in thickness. At the mouth of the Abe Lincoln tunnel, in Chinaman Gulch, it is about four feet thick, while half a mile further west it is fully one hundred feet. This shale seam is

Digitized by Google

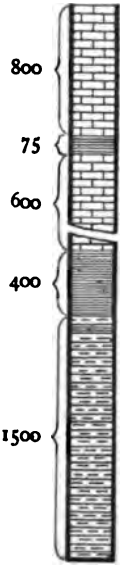


FIG. 1. Section at Pioche.

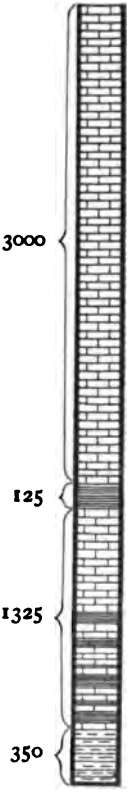


FIG. 2. Section at the Highland Range.

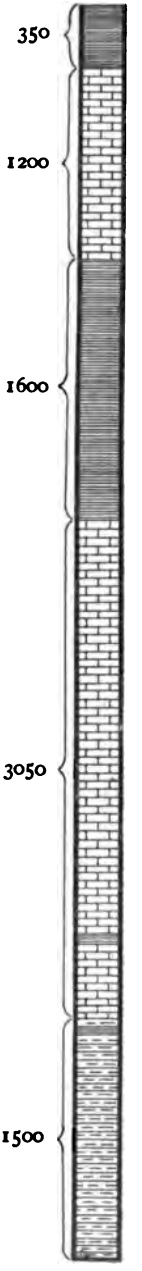


FIG. 3. Section at Eureka.

Digitized by Google

everywhere very fossiliferous, and is typically exposed at the Half Moon-Abe Lincoln mining property. The ore body worked by these companies is a bedded deposit occurring within this formation. Mining operations have thrown out large masses of this material and therefore made ideal conditions for collecting fossils.

This is the zone described by Walcott and Brögger as equivalent to the Paradoxides of the east, and correlated by them with the Prospect Mountain limestone and the Mt. Stephen formations. It is separated from the Olenellus fauna by a distance of 1,000 feet at Pioche, by 500 feet at Eureka, and by 1,100 feet at Highland Range. At Eureka the Dikellocephalus zone is 2,500 feet higher. This formation is, therefore, well nigh midway between the upper (Dikellocephalous) and lower (Olenellus) zones, and could very naturally belong to the Mid-Cambric.

At Mt. Ely fully 800 feet of massive compact silicious limestone occurs above this shale member. The same thing is shown in the Highland Range section, except that there the limestone has a thickness of 3,000 feet. It is unfossiliferous in both localities. Mr. Walcott thinks that the summit of this formation as shown in the Highland Range marks the upper limit of the Cambric section.

The accompanying figures show the relative thickness of the Cambric sections at Pioche, Highland Range and Eureka.

Igneous Rocks.

The Yuba Dyke.

It appears that the early miners attached but very little importance to the presence of the igneous dyke which cut through the center of the mining district. The writer has failed to find any allusion to it in the reports of the old companies, but now it is well known that prospecting is quite unprofitable at any great distance from it.

The Yuba Dyke is situated far up the hillside south of Pioche. It strikes magnetic east and west, and dips to the south at various angles, averaging practically eighty degrees. It varies in thickness from ten to one hundred feet, averaging about seventy-five. In the vicinity of the mines it outcrops almost exclusively in the quartzite, a fact which suggests the thought that its introduction may have taken place prior to the deposition of the superjacent shale. This inference, however, is not correct as the dyke enters the shale for a distance of nearly three hundred feet.

Digitized by Google

This igneous intrusion was not displaced by the anticlinal faulting which thrust the quartzite up into contact with the shale and limestone, and was, therefore, introduced subsequently to the anticlinal movement and the disturbances that immediately followed.

It emerges from the shale just above the Lightner shaft, and extends in an easterly direction up and over the north slope of Treasure Hill. It then passes down through the gulch at the east, rises to a point near the west end of the Boss claim and then divides. The north branch continues in the strike of the main dyke; the other assumes a direction about sixty-five degrees east of south and extends over the hill toward the old Daly East property. It does not continue far until it is lost; the farther it is followed the smaller it becomes, a fact which indicates that it forms but a small offshoot from the principal intrusion. The north branch also disappears a few hundred feet beyond the point of bifurcation It strikes in the exact direction of the Alps mine, which is situated nearly one mile away. A continuation of the dyke was encountered at the three-hundred-foot level of this mine, although there are no igneous outcrops for several thousand feet in any direction. The lithological character of the material as well as the strike dip, and width is almost the same as that at Pioche.

The writer made several attempts to trace the Yuba Dyke through the limestone region to the west of the mines, but failed to find it, except as represented by a few isolated outcrops. Just south of the Lightner shaft it strikes up the hill toward the upper water tank, but it pitches into the shale three or four hundred feet east of that point. The next place at which it was observed was in a tunnel at the Abe Lincoln mine nearly two miles to the west. It does not outcrop at this point, but was accidentally encountered by the miners at a vertical depth of one hundred and fifty feet. The dyke material is involved in a displacement which has apparently brought it from below.

About one mile farther to the west and near what is called the "low divide" its outcrop is observed for the first time in the limestone. For about one mile beyond this point it is covered by wash, and then it comes to the surface intermittently for another half mile. It is lost again for a short distance and then outcrops continuously for three or four miles to Stampede Pass beyond which no attempt has been made to follow it.

Digitized by Google

These isolated exposures are all situated in the projected strike of the dyke at Pioche, a fact which indicates that this igneous body extends throughout the entire distance, but that it does not come to the surface except at a few points. Microscopic examination of samples collected at each of these places shows that the material is all of the same general nature. It appears, therefore, that the Yuba Dyke extends from Stampede Pass in the west to the Alps mine in the east, covering a distance of fully ten miles.

The rock comprising the intrusion is a fairly typical rhyolitic porphyry. The feldspars are highly altered; in fact the only original mineral remaining is the quartz, which gives the material the appearance of a quartz porphyry. The petrography of this intrusion is discussed at greater length in another part of this paper.

At first thought it may appear strange that the dyke at Pioche should be confined almost wholly to the quartzite. Two factors are largely accountable for this condition, first, that the quartzite is now denuded of the higher formations, under which at one time the dyke was likely buried, and second, that the quartzite is much more easily fractured than either the shale or the limestone, and, therefore, offered less resistance to the intrusion of the igneous mass. In other words, the magma penetrated farther into the easily fissured quartzite than it did into the refractory shale and limestone.

It is now well understood that the force of an igneous intrusion may be spent before the surface is reached. In consequence of this loss of energy many dykes never outcrop. This condition is frequently revealed in mining operations. The writer knows of several instances in which dykes were encountered at various depths, while on the surface there is no indication whatever of their existence. During its dying stages such an intrusion follows the strata offering the least resistance, but when in its prime it cuts through all formations alike. This differential selection is well illustrated in Stampede Gap. The dyke outcrops in the limestone and may be followed with little difficulty. At one point it pitches down under a cherty mass and reappears about three hundred feet farther on. The avoided mass is topographically lower than the rock in which the intrusion occurs.

At the extreme west in Stampede Gap the dyke outcrops strongly and continuously for fully three miles. To the eastward

Digitized by Google

for nearly the same distance it comes to the surface intermittently, and then disappears under the limestone capping near the "low divide." At the Abe Lincoln mine, one mile further to the east, it is found at a depth of more than one hundred feet, but still it occurs in the limestone. The first outcrop at Pioche does not reach this number, but comes only part way through the subjacent shale. East of this point it is confined to the still lower quartzite; further to the eastward it pitches into this formation and disappears from the surface. At the Alps mine its uppermost part is three hundred feet below the surface.

The dyke, therefore, does not outcrop, except at a few points where it has probably been exposed by erosion. It should further be noted that from west to east the top of this intrusion is limited by succeedingly lower strata. At Stampede Pass it penetrates the Upper Cambric, while at the Alps mine it is lost in the Lower Cambric.

As before stated the dyke material is highly altered; none of the original minerals remain except the quartz. This is true of samples taken at a depth of fifteen hundred feet in the Raymond and Ely mine. The rock at the Abe Lincoln tunnel is the only exception; here it is fairly well preserved. The crystals are all large, a feature that implies slow cooling, which in this case must have occurred at a considerable depth. The well developed flow-

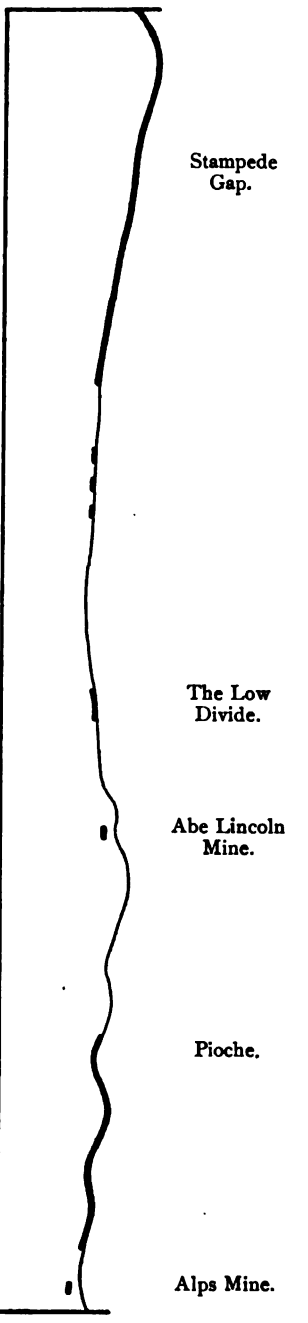


FIG. 4. Section along the Yuba dyke from Stampede Gap to the Alps mine. The heavy line shows places at which the dyke has been found.

Digitized by Google

age structure shows that movement must have taken place after the mass had become crystallized.

It has been shown elsewhere that the movement which resulted in the elevation of the Pioche anticline occurred long before the introduction of the dike. It now appears that the dike is much older than the present topographic features. These facts strengthen the conclusion concerning the remote origin of the Pioche anticline.

STRUCTURE.

As stated elsewhere in this paper, the Pioche Mountains are 15 miles long by 1 mile wide, and trend in a direction about 65 degrees west of north. They are composed of a highly fissured and faulted anticlinal fold, the axis of which does not coincide with the axis of the range, except for a short distance near the central part of the uplift.

In the vicinity of Pioche the quartzite core has been thrust up between the flanking members for fully 1,000 feet, so that it is now separated from the shale and limestone on either side by a fault plane. These planes of displacement are parallel to each other and strike within a few degrees of the mountain axis.

The north one is well exposed near the court house, and extends southeastward through the lower part of the town and up a small gulch toward the old Pioche mine, and then across the flat in the direction of the Alps mine. The dip of this fault is about 70 degrees to the north as shown by an incline sunk upon it at the Bamberger property in the east side of the town.

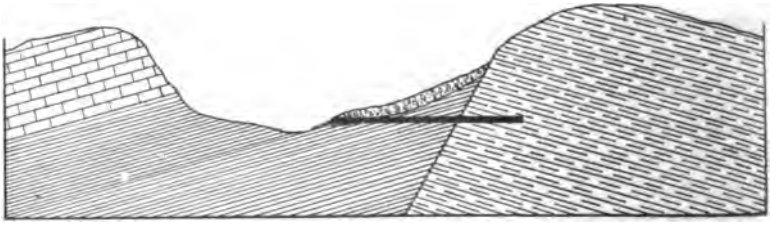


FIG. 5. Section along an old tunnel across the divide from the Williams mine. (Showing fault plane between the quartzite and the shale.)

The other parallel fault is well shown by an escarpment on the southwestern slopes of Treasure Hill immediately south of the town. Its southeastern extension from here has not been traced, but to the northwest it strikes through the low gap, passes the Lightner shaft to the right, extends across the gulch and through

Digitized by Google

the low pass at the northwest of the Raymond and Ely ground. Its dip is to the southwest about 60 degrees. This is well shown in an old tunnel just across the divide from the Williams mine. The tunnel begins in a loose quartzite talus and after passing through seventy-five feet of this material it enters the shale, which has been protected from erosion by the overlying talus. It continues in the shale for one hundred and eighty-five feet, at which point it crosses the fault plane and passes into the quartzite. This is shown in the accompanying figure.

Another interesting feature is herewith shown. The fault plane is without doubt primarily responsible for the existence of the low divide shown at the left, the original position of which was immediately above the plane of displacement. As the formations were cut down differential weathering carried it farther and farther to the west, so that now the fault plane is fully three hundred feet to the right of the pass and a considerable distance above it.

It may be thought that this crowding toward the shale and limestone is wholly due to the greater resistance to erosion offered by the quartzite. This is without doubt true of the shale, and especially so in this case, as the ends of the beds are exposed to the weathering. And, indeed, the limestone has also retreated, but largely because of the undermining action of the decaying shale, as proved by the almost vertical cliff of limestone which faces the gulch. The limestone is exceedingly hard and vitreous, and withstands weathering almost, if not quite, as well as the quartzite.

The structure of the anticline is further complicated in the vicinity of Pioche by the existence of a number of cross faults, one of which displaces the Raymond and Ely-Meadow Valley fissure vein about half way between the Lightner shaft and Meadow Valley shaft No. 3. It is suggested by Howell and Spurr that a southwest-northeast fault is the cause of the gulch in which Pioche is situated.

It should also be noted that the anticline pitches downward at its western extremity and abuts against the outlyers of the Highland Range. As might be expected under such conditions cross wrinkling has occurred, resulting not infrequently in transverse faults. Immediately west of Mt. Ely one of these has resulted in a displacement of fully four hundred feet. This is best shown in the Half Moon gulch on the south side of the mountains.

Digitized by Google

The stratum most easily traced is the fossiliferous shale, which carries a bedded deposit of ore. The dumps from mining pits have made great quantities available. One can stand at a considerable distance and trace it from the west past the Himon mine and around the hillside to the old Chisholm workings. A few hundred feet to the east the shale suddenly curves downward,

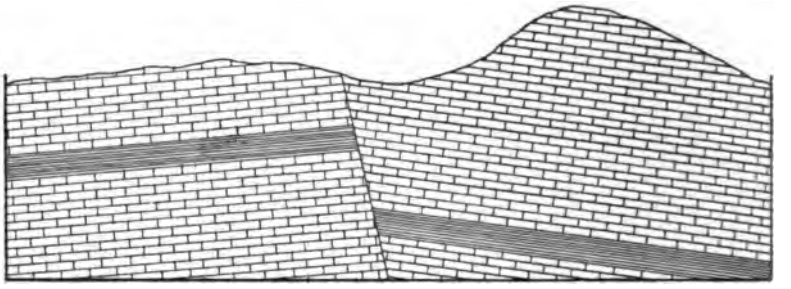


FIG. 6. Section east and west through Mt. Ely, showing the elevated position of the downthrown block.

thins out and disappears. It continues four hundred feet lower on the property of the Half Moon Mining Company. It then passes around the hill to the east and is lost under Mt. Ely. The fault dips to the east about 75 degrees and is readily detected even at a distance.

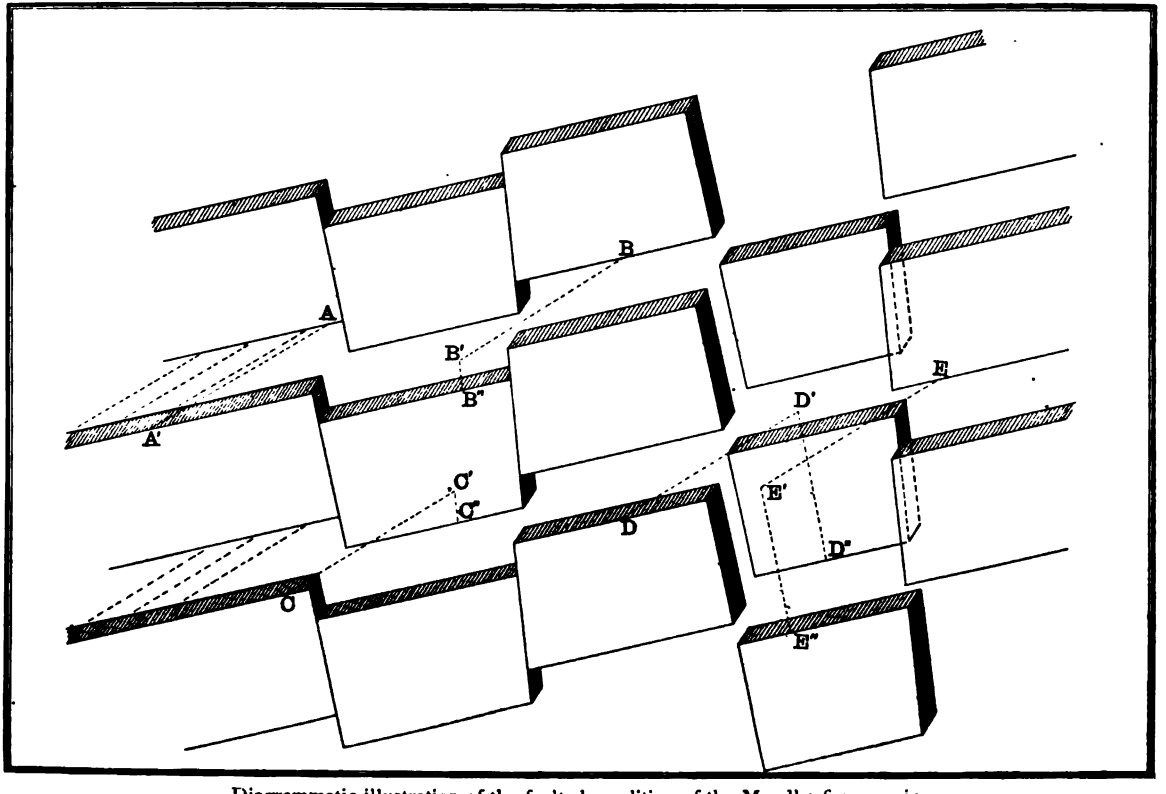
A very interesting case of faulting occurs at the Mendha mine about six miles west of Pioche. The country rock of the immediate neighborhood is limestone of the Cambric age, and correlated with the upper members of the Pioche anticline. None of the shale and quartzite formations are revealed.

It should be remembered that the Highland Range at the west extends in a north and south direction, and that the Pioche anticline at the east joins this range at approximately right angles. A number of minor crumplings occur where these two ranges meet, one of which extends across the Mendha mining property in a direction 15 degrees east of south. The strata of this uplift dip in a direction 75 degrees west of south at an angle of 30 degrees. An igneous dyke traverses the anticline parallel to its trend and near its apex.

The Mendha fissure vein lies within the western members of the uplift and strikes east and west, making an angle of 75 degrees with the axis of the anticline and 15 degrees with the direction of

Digitized by Google

Digitized by Google



Diagrammatic illustration of the faulted condition of the Mendha fissure vein.

Digitized by Google

the dip of the beds. This point was of importance in working out other structural features. The deposit is a true fissure vein, varying from one to six feet in width, and is quite continuous.

The vein was formed before the folding began. As this movement progressed slipping occurred between the component beds and displaced the ore deposit about 50 feet.

The mine workings thus far show the presence of two of these fault planes. As noted elsewhere they are both of the reversed type. This displacement has brought about the condition that the lower workings of the mine are farther south than those nearer the surface, although the vein dips to the north.

A secondary mineralization followed this faulting, and resulted in the deposition of a highly silicious ore-bearing material along the bedding planes.

Complicated as these conditions may appear they were made more so by the occurrence of another series of faults cutting the fissure vein at right angles. The country was thus cut into blocks, every other one of which was thrown down and the intervening one up. This gave the mine operators endless trouble, as no general rule of interpretation appeared to apply.

It may be stated, then, that the fissuring and faulting occurred in the following order: First, the east and west fissuring which culminated in the formation of the Mendha vein; second, the slipping between the beds, during the anticlinal movement, which resulted in the displacement of the fissure vein and in the secondary mineralization; and third, the cross fissuring and faulting, which displaced the two series of deposits already existing.

The accompanying plate illustrates in a diagrammatic way the faulting just described. The dotted lines indicate the direction of the movement. The intricate condition is the result of but two series of displacements, the first of which carried A to A'. After the first occurred the vein may be considered as consisting of parallel parts separated both laterally and vertically. The second slipping broke up this regular arrangement and produced the condition shown in the plate. The first faulting

carried A to A',
" B to B', and the second B' to B'',
" C to C', " " " C' to C'',
" D to D', " " " D' to D'',
" E to E', " " " E' to E''.

Digitized by Google

Another interesting case of the relation of an ore body to the structural features occurs at the western extremity of the anticline. Some time ago a vein was discovered at this point and later it was developed to a depth of nearly one hundred feet; the property appeared to be a promising one and consequently several "extensions" were located. The vein outcropped for a short distance only, but the new claims were located with almost mathematical precision along the direct path of its strike. The locators were thus carried beyond any surface indications and into a gravel-covered area. They were confident that the ore body could be found and decided to sink a shaft through the wash to the bedrock ; then, if necessary, to run crosscuts to locate the ledge. When the writer examined the property the shaft had reached a depth of 80 feet; the bottom of the workings were still in the gravel and indications pointed to the conclusion that bedrock was still much deeper. The outcrop was studied with care, as was also the vein in the workings of the original locators. The deposit occurred between limestone beds and consequently dipped with the formations. Surface indications showed that the limestone formed part of the Pioche anticline, which was known to pitch downward at its west end; and, further, that the limestone outcrops did not strike in a straight line, but rather in a curve. Thus it follows that the ore body deposited between the beds would swing round with the outcrops of the anticline. The conditions are shown in Fig. 7.

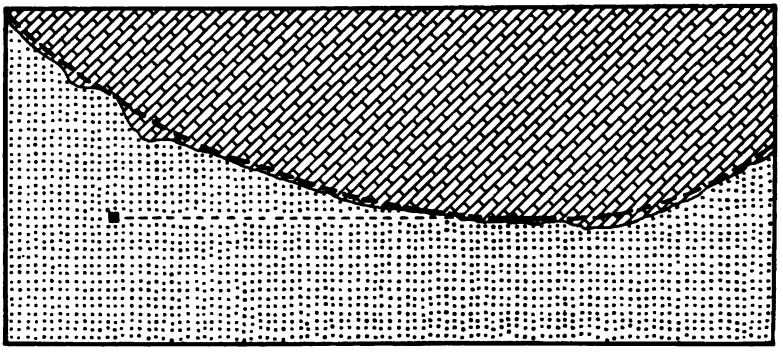


FIG. 7. Point mine and immediate vicinity. (Showing the curved nature of the outcrop.)

Although the new locators were situated in the direct strike of the vein as indicated by the short outcrop, yet they were several hun-

Digitized by Google

dred feet to one side of the ore body, or at least from its normal position in the limestone.

Relation of the Structural Features to the Topography.

The faults of the region bear a most remarkable relationship to the topography. Under ordinary conditions the upthrown block of a faulted area is left in higher relief than the depressed block. Erosion, however, would eventually reduce both to a common level, but in many instances in the Pioche Mountains this weathering process has been carried further, so that now the *downthrown* blocks form the *highest* points. The process is well illustrated in the faulted area at the Half Moon mine (Fig. 6). Mt. Ely which is just above the mine is the highest point in the range, and yet it marks the position of a block thrown down, a relationship illustrated in the accompanying figure. A similar condition exists, moreover, in the hill on the west side of the Half Moon gulch. The fault is normal and strikes nearly east and west. It dips to the south and the throw is about three hundred feet. Nevertheless, the downthrown block now forms an escarpment fifty feet high. The direction of displacement may be traced by means of the fossiliferous shale and adjacent limestones.

Another illustration of this condition is shown about three miles south of Pioche at the Gladstone property, where a block of quartzite has been thrust up into the limestone, and, notwithstanding its elevated position, it marks a low area in the topography of the region.

Just across the divide south of Pioche several smaller faults show the same thing. The limestone which has been thrown down into contact with the quartzite now stands in relief.

The general configuration of the Pioche anticline reveals the same condition. The quartzite core has been faulted upward one thousand feet, and yet, except for about two miles, its elevation is less than that of the flanking limestone. It is true that the throw of the displacement decreases both toward the east and the west, but it does not reach zero, except perhaps at the extreme eastern and western quartzite exposures. West of Pioche the south limestone member rises nearly one thousand feet above the *upthrown* quartzite.

The condition means this at least: the great thickness of limestone and shale once superimposed on the quartzite, and now but

Digitized by Google

partly represented by the flanking members, has all been removed, and in addition to this the quartzite itself has been eroded, but to what extent cannot be stated with any degree of accuracy. Thus, at least two thousand feet of limestone and shale have been removed from the upthrown central core while the flanking members have actually weathered into relief.

Perhaps a partial explanation lies in the fact that during the process of folding the greatest stress was brought to bear along the anticlinal axis, a part which will, therefore, offer less resistance to erosion than the flanking members. While this suggestion appears possible in regard to the mountains as a whole, yet it does not apply to the cases where the faulting is not accompanied by folding. It may be that local conditions such as rock texture, etc., are partly responsible, but inasmuch as it is quite the exception to find a case in which the upthrown block stands in relief above the depressed one, it appears that there is yet something unexplained. This will be discussed at greater length in considering the origin of the Pioche Mountains.

Origin of the Pioche Mountains.

The Pioche Mountains extend directly across one of the long north and south valleys o southeastern Nevada. In order to gain some idea of their relations to the surrounding country, let the reader imagine himself standing on these mountains and facing the north. Before him is Duck Valley; behind him is Meadow Valley; to the northwest is the Ely Range, and to the southwest the Highland Range. Cedar Range lies at the northeast and Mormon Range at the southeast.

Duck Valley is broad and flat. The hills at the east are low and rolling, while those at the west are slightly sharper. The valley floor is covered with a deep layer of recent wash. The whole northern section is much rounded and shows signs of long erosion.

Meadow Valley, at the south, is quite similar, except that in Tertiary times a volcanic outburst dammed its waters and converted it into a lake or dry basin, into which the intermittently flowing streams carried their loads. In the course of time the valley was filled as high as the top of the volcanic obstruction, which was then cut down, and through the outlet thus afforded the larger part of the Tertiary beds was removed. Since then the

Digitized by Google

valley has been cutting deeper and deeper. In the north it is broad and open, while at the south it gradually narrows and deepens until, in the vicinity of Caliente, it forms a typical box canyon. With the exception of this recent Tertiary deposition and subsequent erosion the topographical features bear evidence of great age.

The Ely Mountains comprise formations ranging from the Cambric to the Carbonic. The Highland Range is composed chiefly of Cambric strata, although the Siluric and the Devonic are represented.

The Cedar and Mormon Ranges are formed wholly of Tertiary volcanics, which have completely covered the preëxistent formations.

The stream running from Duck Valley into Meadow Valley has cut directly through the Pioche Mountains. According to the old explanation that a mountain so affected by a stream is always younger than the stream itself, we should be forced to the conclusion that these mountains have arisen across this valley since its stream course was determined. There is every evidence to believe, however, that this is not the case, but that the mountains have been discovered by the stream. In other words, they are mountains of circumdenudation, so far as the present topography is concerned.

The evidence at hand leads us to believe that the whole country has been denuded of the higher Paleozoic formations, which even now have vestigial representatives in many parts of this region.

A correlation of the Cambric sections in the Pioche and Highland ranges shows that fully two thousand feet of the upper beds have been removed from the Pioche Mountains. In the Highland range there are other strata aggregating two thousand five hundred feet before the Trenton horizon is reached. The Paleozoic section as a whole must have had an enormous thickness.

It has already been shown that the topography of the Pioche Mountains has been established with no apparent regard for the faults and other disturbances of the region. Indeed, the anticlinal movement and its accompanying phenomena had all been completed long before the present topography was outlined. This means, then, that the anticlinal movement and its attendant faulting occurred while the existing formations were deeply buried under others which have since been removed.

Digitized by Google

It has already been noted that the anticlinal axis and mountain axis do not coincide, except where they cross. If one imagines the fold divided into four quadrants, and so eroded that the northeast and southwest parts remain while the other two are carried away one may have in mind the general relation of the anticline to the mountains. The northwest and southeast members are now represented by a few vestigial exposures, while those at the southwest and northeast form the backbone of the mountains. It follows that while in the main it is true that the anticlinal roll has been a factor in determining the present topography, it is evident that in many ways erosion has acted absolutely regardless of it. This condition is susceptible of but one interpretation; that the anticlinal movement and its accompanying disturbances are much older than the present topographical features, and, further, that these mountains are but remnants of the great Paleozoic formations which at one time covered this entire region.

So far as known the whole of this country was raised above water level near the close of Paleozoic time; since then it has been subject to erosion. It is not at all improbable, however, that a condition of peneplanation has been reached since then, and that through rejuvenation it is now undergoing the process for the second time.

Streams traversing an uprising peneplain have little or no regard for preëxisting structural features. Upthrust and downthrust blocks are subjected to the same treatment. Anticlines are traversed as easily as horizontal beds. The resulting topography will be governed wholly by the ability of the various formations to resist the eroding influence to which they are subjected. Therefore, it is possibly true that the stream which cuts across the Pioche Mountains is older than the present topography, but it does not follow that the mountains were elevated across its course.

The Pioche Mountains. then, are the immediate result of circumdenudation; in other words the discovering processes of peneplanation.

The Highland District.

The Ely Mining District in which Pioche is situated forms an area six miles square, the western boundary of which lies just beyond the Point Mine. The Highland District is of equal size and adjoins it on the west. Stampede Gap, a broad open canyon, extends east and west through the central part, and separates the

Digitized by Google

Ely Mountains on the north from the Highland Mountains on the south.

There are several igneous dykes occurring here, chief among which is the western extension of the Yuba Dyke. Wherever ore has been found it is closely associated with these intrusions. At the time of the writer's visit to the region some promising prospects were being developed at various places. The Mendha mine, to which reference will be later made, is situated within this area.

The stratigraphy is almost identical with that at Pioche, except that the higher Upper Cambric is preserved. A section of the Highland Mountains taken on the west slope is given elsewhere in this report. The limestone covers by far the greater part of the district.

About two miles to the northwest of the divide at Stampede Pass the intrusion of a granite boss has tilted the strata so that the complete series down to, and including the quartzite, is exposed. Metamorphic and dynamic action has so changed the original sedimentary condition that the section is of little stratigraphic interest. The quartzite is usually hard and vitreous; the shale is altered to a mica schist, and the limestone to marble. No traces of fossils were observed. The granite extends for several miles to the northward and forms the core of a series of hills which are but slightly subordinate in altitude to the mountain axis. It was reported to the writer that some good contact deposits of copper ore had been found.

The ridge which forms the divide at Stampede Pass reveals a number of interesting conditions. It is nearly one mile long and rather narrow with quite precipitous slopes. The crest of the ridge strikes in a north and south direction. A few hundred feet from the northern extremity of this divide the country rock, limestone, is suddenly replaced by a very large mass of iron ore, which consists of magnetite, hematite, and limonite, the two latter predominating. Farther to the south the iron slowly gives place to garnet; the transition is so gradual that a separating line or zone cannot be established. With the loss of the iron the garnet becomes almost pure and very massive, although crystals are common. From this point on iron pyrite gradually enters until at the south contact with the limestone it forms perhaps 50 per cent. of the mass. Taken as a whole this iron garnet body is about three thousand feet long by two thousand feet wide.

Digitized by Google

The iron oxides were mined at the time the smelters were in operation at Pioche; they appear to be fairly pure, but no results of analyses are at hand. Molybdenite is associated with the pyrite and garnet at the south contact; but to what extent this mineral occurs cannot be stated as no prospecting has been done for it. The entire mass is traversed in several directions by veins of almost pure quartz. An investigation as to the source of this apparently foreign material would be interesting.

In most respects this great body appears to be the results of contact metamorphism. Such large quantities of iron are not, however, necessarily associated with that process, in fact they are somewhat unusual under such circumstances. The most singular feature of all is the apparent absence of any igneous intrusion by which these conditions could have been brought about. It is true that the Yuba Dyke passes within a thousand feet, but it is entirely too small to produce the result here shown. An examination of the country to the southwest may reveal the presence of some igneous body sufficiently large to account for the condition.

PART II. PETROGRAPHY.

THE IGNEOUS ROCKS.

So far as known all of the igneous rock of the district, with but one exception, is confined to the Yuba Dyke. The exception is a small mass of tuff apparently interbedded with the quartzite at the Eiler property about three miles northwest of Pioche. As elsewhere stated, the dyke extends from the Alps mine in the east to Stampede Pass in the west, covering a distance of about ten miles. The average width of this intrusion is probably seventy-five feet. It was apparently introduced long before the present physiographic features were outlined. In consequence of its age the material of which it is composed is now highly altered. Of the original minerals, quartz is practically the only one remaining. Specimens of the dyke brought from a depth of fifteen hundred feet at the Raymond and Ely mine show almost as much alteration as those from near the surface. The rock from the Abe Lincoln tunnel is the only exception, in that it is remarkably well preserved. It shows a number of interesting features which will be discussed in a later paragraph.

Digitized by Google

Digitized by Google

FIG. 1. Rhyolitic porphyry from Abe Lincoln mine.

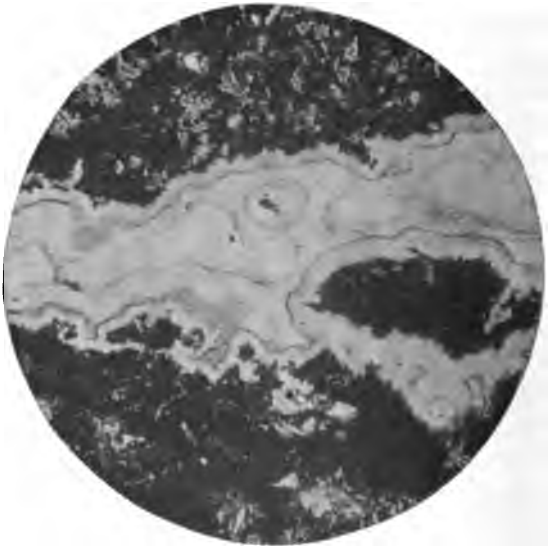


FIG. 2. Altered tuff from the Eiler property.

Digitized by Google

The igneous rock comprising the dyke in the vicinity of Pioche may be described as originally a rhyolitic porphyry composed of quartz, feldspar, mica, iron ores, and probably hornblende. Of these minerals the feldspar has practically disappeared; only vestiges of the mica and hornblende remain, but the quartz is still clear and fresh. A hand specimen looks not unlike a quartz porphyry with its typical felsitic groundmass. The rock encountered at the fifteen-hundred-foot level in the Raymond and Ely mine carries a fairly rich dissemination of minute pyrite crystals.

The igneous rock at the Abe Lincoln mine is composed of quartz, orthoclase, a little plagioclase, biotite, iron ores and a little hornblende, all of which are inclosed in a glassy groundmass showing pronounced flowage structure. The crystals are all fairly large and with but few exceptions are remarkably well preserved. They show the result of considerable resorption, which, of course, occurred at the time marked by the flowage. It appears that the original crystallization must have taken place under conditions of slow cooling, perhaps at great depth. The step toward re-fusion, indicated by the resorption and flowage, may have been due to release of pressure occasioned by the sudden advance of the dyke toward the surface. Under such conditions the upper and outer parts would normally chill rather quickly and thus form a glassy matrix enclosing the corroded crystals. It is evident that the mass had become well crystallized when the re-fusing process began, and that the second cooling was very sudden.

The tuff occurring at the Eiler property is apparently interbedded with the Lower Cambric quartzite, and, therefore, reached the surface at some time during the period while this formation was being deposited. It was encountered in an open cut by some mining prospectors. It breaks readily, and with a hackly fracture. The hand specimen is yellow, and in that respect looks not unlike molasses candy. The fragmentary nature of the rock may be partly detected by the unaided eye. Under a lens this condition is plainly seen. A thin section reveals the fact that all of the original minerals have gone, and that the rock is now composed wholly of epidote and chalcedony. The epidote occurs massive, although minute individual crystals are not uncommon. The chalcedony forms botryoidal and mammallary aggregates along the crevices and in the cavities. It comprises perhaps seventy-five per cent. of the entire mass.

Digitized by Google

From an economic standpoint the igneous rocks of the district are very important. They appear to have been the source from which all of the ore deposits were derived. This is discussed at length in another part of this paper.

Digitized by Google

THE HISTORICAL DEVELOPMENT OF GENERAL CHEMISTRY.*

By WILHELM OSTWALD,
Professor at the University of Leipzig.

Third Lecture: Molecular Theory Including Osmotic Pressure.

Ladies and Gentlemen: At our last meeting we first obtained the general concepts of chemistry, namely, the concepts of elements and compounds; then, starting from these general concepts, investigated the most general laws which can be connected with them, *i. e.*, the laws relating to weight, and finally by aid of its connection with weight we obtained a definition of chemical change.

To-day we come to another very general law, though not quite so general as the other. The law to which I allude was discovered at the same time, or a little before the time that the law of combining weights in its larger acceptance (the law connected with the atomic theory of Dalton) was developed. It started in a most peculiar way. Humboldt, the famous traveler was preparing for a voyage to South America and included among the various questions he was to investigate the question of the composition of the atmosphere. It was not known at that time whether the atmosphere varied in its composition with the latitude, or with the relative area of sea and water, or not, so that Humboldt considered it a fruitful and important question to think about.

When Alexander von Humboldt studied the question, however, he found that no certain means of arriving at a theory was known at that time, and consequently, that it was necessary to start the investigation by finding such a means. As he could not do it for himself (for he had not time enough, and possibly also not chemical experience enough, having begun his career as a mining engineer), he associated with him a very young man, a very promising young man, who was selected for him by one of his acquaintances in Paris. This man was named Gay-Lussac. Gay-Lussac worked

* Course of six lectures delivered in the Department of Chemistry of Columbia University, in Havemeyer Hall, January 26 to February 2, 1906. Reported stenographically. Lectures 1 and 2 were printed in the January, 1906, number. Copyrighted by the School of Mines Quarterly.

Digitized by Google

out the various details of air analysis, according to the theory of Berthollet and found at last that the most exact way of analyzing air was to mix it with a surplus of hydrogen, to explode the mixture, and finally to measure the volume remaining; the very method indeed used in our day as the surest and most exact method of analyzing atmospheric air. This method was also developed by Volta, the famous inventor of the voltaic pile, in the early stages of Volta's scientific career.

Now the analysis of air by this means depends upon the ratio of the volumes of the remaining and disappearing gases. The operation is as follows: A certain volume of air, after being measured, is mixed with a certain amount of hydrogen and the total volume measured. Then the mixture is exploded. By the explosion oxygen, with a proper quantity of hydrogen, disappears, forming water. The volume of the remainder is now measured. Since, of course, the quantity of oxygen will be a certain part of the disappearing volume, the question which arose was, what part of this volume is oxygen? Experiment showed it to be exactly a third part. In other words, when oxygen and hydrogen unite one volume of oxygen combines with two volumes of hydrogen, and this ratio by volume was found to hold as closely and exactly as measurements could be executed at that time. Indeed, former investigators who had measured this ratio, found almost exactly the same result in one or two cases, but no one of them suspected that the ratio of ingredients was more than a coincidence; and no one dreamed that there existed any general law in connection with these ratios.

After finishing this work, Gay-Lussac's connection with Humboldt ceased. Humboldt went on his voyage while Gay-Lussac continued his work with the more general questions, although using his experience with hydrogen and oxygen as a means for further developments. He endeavored to discover if other substances united also in simple ratios by volume, or if this was only an accidental ratio. The result was that in the ten or fifteen cases which he examined he discovered that there were exact ratios for the union of each element with another. Later, in 1802, he published a paper on this subject in which he announced his discovery that when gases undergo chemical change, the ratio of the disappearing gases to those formed (indeed, the ratio between all gases concerned in such a chemical change) can be expressed by

Digitized by Google

small, whole numbers like 1, 2, 3 or 4. He did not discover any higher number than 4.

This was a very important discovery, but its importance was not recognized for some time. You will remember that the first application of Dalton's idea, a year later, in 1806, in connection with the idea of combining weights, was not evident at once. The same was true with Gay-Lussac's law of combining volumes. At first no one brought together the two laws. Of course both of them still had a certain amount of indistinctness, especially the law of the combining weights, and therefore it was somewhat venturesome to put them together and expect much to result. But later, when the ideas of Dalton were confirmed by the investigations of Berzelius, Gay-Lussac at once turned his attention to the relation of the volumes of the gases, and found that all chemical elements or substances not only unite according to their combining weights, but also unite in equal volumes, or in volumes which stand in a simple relation to one another. This means nothing more, however, than that equal volumes of different gases contain such weights as are expressed by their combining weights, or by simple multiples of these combining weights. And this leads only to the conclusion that the specific gravity of a gas is either identical with the combining weight, or stands in a simple relation to the combining weight.

To make this consequence clearer let us consider the very simple case of chlorine and hydrogen. The law of Gay-Lussac tells us, then, that equal volumes of hydrogen and chlorine unite to form a chemical compound; while the law of combining weights tells us that as between the weights of hydrogen and of chlorine combining there is a certain ratio.

The weights of equal volumes thus means nothing more than that the specific weights of different gases are related as the combining weights.

As this was just what Berzelius was interested in, he tried at once to develop a comprehensive theory of gaseous compounds and their relations to combining weights from this general discovery of Gay-Lussac.

I do not know if I told you that Gay-Lussac was quite convinced of the truth of the atomic hypothesis. He doubted it in the beginning, but when he tested it by means of analysis and found that the analyses corresponded quite exactly with the assumptions contained

Digitized by Google

in this hypothesis, he regarded the hypothesis as proven and held to it. Now, his first idea was that equal volumes of different gases should contain an equal number of atoms. It seemed rather likely that it should be so, for you know that different gases behave in a similar way. Gay-Lussac had already discovered the law that all gases have the same rate of expansion with increased temperature, *i. e.*, vary in volume or pressure in the same way when the temperature is changed, independent of the nature of the gas. And Boyle had discovered another law holding good for all gases, that the volume of the gas is inversely proportional to the pressure, and the nature of the gas has no influence at all. These were general laws, then, and independent of the chemical nature of the gas. Therefore, since a number of the properties of gases proved themselves dependent upon something more general than their specific chemical nature, the law was not far to seek that these properties must depend upon the equal constitution of the different gases; in an equal volume, then, an equal number of atoms must be present.

Berzelius then published his views, choosing the atomic weights, as he called them, in such a way that they were proportional to the densities of the various gaseous elements. This could be done, of course, for the analysis of compounds either by synthesis or analysis in the natural sense, shows that the ratio between the different combining weights is the same; and when, as is often the case, there is more than one combination between two or more elements, there is a certain freedom in the choice of the multiple of the combining weight to be used as the true unit. Berzelius made use of this freedom of choice and so obtained combining weights which were proportional to the volume weights of the different gases, of course under the same conditions of pressure and temperature. After publishing his views, however, he encountered a difficulty, which caused him to abandon for a short time the whole theory of combination, as it was called. This is a remarkable instance of the freedom of scientific thought with Berzelius. Berzelius was so little enamored of his own ideas that he judged them more even severely than he judged the ideas of others; at least in his younger days this was so. When he became older, the general ossification of the brain, which always accompanies age, was evident, also, in this most powerful brain, and the same man who in his younger days wrote that science was the freest of all possible

Digitized by Google

lands, and that every man has the right to do anything in science, if only it be true and correct, was the same man who in the last five or ten years of his life waged the bitterest possible war against the whole science of his time.

This is a general fact to be observed in the most influential scientists. Of course every science has its own rate of progress, but when such a powerful man appears in it he always increases the rate, and all science advances with him. But science is an organism of a much longer existence than that of a single man, and it is just the increased speed which is caused by this man that is often the cause of his undoing. He cannot develop himself as quickly as his science does under his influence; *it* develops, so rapidly that, when he becomes old, he must either step aside and let science go by herself, or else fall under her wheels and be crushed. In this way Berzelius, who did not step aside, was crushed, and his last days were unhappy. Indeed, if you will investigate the personal experience of any great scientist you will find this to be almost invariably his fate. Science is a very severe deity and cares not for any man; for after he has served her purposes, she casts him aside and leaves him to look after himself.

Now Berzelius was very severe in the criticism of his own ideas at this time and discovered at once a number of cases which did not agree at all with his first idea. Let us consider the case of hydrogen and chlorine, for example. As you know, two volumes of hydrogen chloride are formed from one volume of hydrogen plus one volume of chlorine, and it is at once apparent that if there are, say, a thousand atoms in this volume of hydrogen, and presumably a thousand atoms of chlorine in its one volume, and one atom of hydrogen unites with one atom of chlorine, there cannot be formed more than a thousand atoms of hydrogen chloride, but these thousand atoms are supposed to fill not one volume, but two volumes. In one volume consequently there must be but 500 atoms, and it is utterly impossible to carry through the general assumption that in all cases the density will be properly expressed by the combining weights. For the combining weight of hydrogen chloride is 36 47, while its greatest density is but one half of this.

If we start from the assumption that equal volumes of gases contain the same number of atoms, then the atomic weight of the hydrogen chloride cannot be 36.47 but should be only half of it; and that would mean nothing but that the hydrogen chloride con-

Digitized by Google

sists of half an atom of hydrogen and half an atom of chlorine, but this is again a contradiction, because atoms cannot be divided. Therefore there is a certain contradiction in this idea. We get the same contradiction if we unite two volumes of hydrogen and one volume of oxygen to two volumes of water vapor. This means that an atom of hydrogen must take up half an atom of oxygen to form one atom of water, if the law of the proportionality between combining weights is correct.

Berzelius dropped the matter entirely at this point and expected some other discovery to clear up this matter. It was useless to attempt artificial explanation where such an obvious difference and utter contradiction was evident.

In a very short time after this result was reached, an explanation was offered from two different sources which turned out to be almost the same, and by which this difficulty was removed, so to say. The men who tried and published these explanations were an Italian physicist, named Avogadro, and a scientist of the very highest standing, a Frenchman named Ampère, the same man who discovered the law of the mutual action of currents. Now both tried to explain this fact in the way well known to every chemist, *i. e.*, by the assumption of some other kind of indivisible units in the gas which are different from the simple atoms of Dalton. These we now call molecules, they called them otherwise, however, in their first papers; but to avoid any difficulty in understanding I will accept at once the modern expression. The idea was simply that we would get by means of halves of these units the number of units in the gas. It is not possible to assume half the atoms; we are forced to assume exactly the inverse thing, namely, that the material units in the gas are not simply atoms but made up of more than one atom; then they may be divided without any necessity of dividing atoms, and the whole thing may be plotted out. For example, we assume that a gas does not consist directly of atoms, but of pairs of atoms; that two atoms form a combination, a unit of their own, and that these units are concerned in the law of combining volumes of gases. Then we can get the whole matter in order. Thus we can assume that hydrogen in the gaseous state is made up the material units called molecules in such a way that every molecule consists of two atoms; and in the same way chlorine is made up of molecules, each consisting of two atoms, while hydrogen chloride is made up

Digitized by Google

of molecules, each of which consists of one atom of hydrogen and one atom of chlorine. Then the whole difficulty is effaced. The 1,000 molecules of hydrogen and chlorine are each made up of 2,000 atoms, and 2,000 molecules of hydrogen chloride are formed, each consisting of one atom of hydrogen and one atom of chlorine.

Now it is most interesting to observe the standpoint of Berzelius toward this suggestion. He had already commenced his "Jahrbericht"—his account of all chemical and physical work done in a certain year. This was one of the most important inventions of Berzelius. You know in our times every science has its yearly account of all work and discovery relating to it—in the German language you will not find any science without its Year Book. And as chemical investigations and facts came into existence the "Jahrbericht" of Berzelius kept an account of them, which he delivered to his own academies and then published in a German translation. This was continued for a number of years most faithfully by his pupil Woehler. In his "Jahrbericht" Berzelius expressed his opinions about the use of atoms and molecules, and his view was not altogether favorable to this idea. He was quite willing to grant that by such assumptions the laws of the volumes of gas could be explained, but these assumptions do not explain anything else. They were made just for the purpose of explaining this simple fact and to explain any fact you can always invent some possibility, although this possibility is quite useless except perhaps for the purpose of teaching, because we do not progress by such an assumption, but only express the same thing by a picture instead of by a numerical ratio. And then before Berzelius declined altogether to accept this view, he added, if there should be found anything connected with the same relations, which could be explained as well, or related more closely, by such assumption, he was ready to accept the explanation of the molecular hypothesis. But so long as the molecular assumption only explains a single fact it does not count for very much and science is only retarded by such a round-about way of stating something which could be stated in a shorter and better way. Indeed the ideas of Avogadro and Ampère remained almost forgotten for a long time and only developed in the way that Berzelius foresaw in his day. Only when after the beginning of the development of organic chemistry it appeared that there was another kind of action with these equal volumes of gases, did it become evident that there

Digitized by Google

was some utility, some truth, some more general relation connected with these ideas of a molecule, and that this idea could be applied with success as a useful idea in science. This recognition came about by the promulgation of a scientific discussion which was connected with the proper formula to be given to chemical compounds.

If we compare the composition of alcohol, C_2H_6O, with ether, $C_4H_{10}O$, and water, H_2O, we do not find much relationship between them; but if we double the formula of alcohol we get $C_4H_{12}O_2$, and the formulæ can be brought into the following relation: If we assume a radical substance of the composition C_4H_8, then ether can be considered as the first hydrate of this compound, of this hydrocarbon, C_4H_8, and a second hydrate would be alcohol. This was indeed the first idea of the relation between these formulæ of ether and alcohol, ether being considered as a first hydrate and alcohol as a second.

Now this idea is dependent upon the way we write the formula of alcohol. In that day the formula was the same as that we are using to-day, C_2H_6O, and there was much discussion as to whether this was the right way or whether the formula should be written $C_4H_8 \cdot 2(H_2O)$ or $(C_2H_6O)_2$. There was no way of deciding the question at that time, because the assumption that the gaseous volume of organic substances shows the formula was not made at that time and had still to be proved. Therefore the question rested upon other questions: Are there reasons for writing the formula of alcohol in this way, $C_2H_4H_2O$ or $C_4H_82(H_2O)$, and the formula of ether in this way $(C_2H_4)_2H_2O$, or $C_4H_8H_2O$? Is alcohol related to ether in this way or in the other way? This question was decided by Williamson, who in a most masterly piece of work explained the following idea:

I will assume knowledge of the fact of the homology of organic compounds; I mean the fact that by adding CH_2 to quite a similar compound in organic chemistry alters that compound. Williamson argued in this way: If there are two radicals in the ether it must be possible to build up an ether which contains two different radicals at the same time. Now at this time it was important to decide this one question, and he showed in a paper that it was possible to turn out any ethers containing ether with any described radical in it, while it was impossible to get alcohols with different radicals in them; therefore the general formula of alcohol should be

Digitized by Google

$C_2H_4H_2O$ (or C_2H_6O), and of ether $(C_2H_4)_2 \cdot H_2O$, or now $(C_2H_5)_2O$.

In this way Williamson introduced the general method of deciding the question of constitution by forming such compounds that may be foreseen by some basic constitution and to decide such questions in this way. But this is a question we shall deal with on a later occasion. The main thing is to show that by choosing the chemical formula in such a way that equal volumes of gases are expressed, the purely chemical relations between the substances concerned could be expressed in a more simple and more natural way than otherwise. This was the missing link, and this is the reason the molecular hypothesis was introduced, and we can see at once that by it these conceptions of organic chemistry based upon the composition of such quantities as exhibit equal volumes in gases, the whole system of organic chemistry can be made much more simple and much more logically related than otherwise.

Then after this served as an introduction, the molecular hypothesis in chemistry went on rather quickly and emphatically. You will find certain definitions in every text-book — I have not been able to trace the first inventor, but it would be interesting to do so — that atoms are the smallest possible parts of matter which can not be divided any more, or which by division would yield other kinds of matter, and molecules are the smallest particles existing in gases or capable of existing in gases. Now it is the queerest thing that nobody ever tried to carry out any experiments to show the truth or to show the scientific meaning of these definitions. Nobody tried to find the smallest particle of a gas and determine its quantity. The whole thing rested, and rests in our day still, just on the assumption that molecules are the smallest parts existing in agas, and if we assume this we can deduce a lot of other things.

Now for us it should be of course a most important task to find out if there is something experimentally definable behind these hypothetical ideas, and how the thing may appear if we remove all these hypothetical garments and show the facts plainly as nature created them. It may be done and in a very simple way. We have alluded already to the law of gases, the law that the pressure and volume are inversely proportional to one another in such a way that the product of pressure and volume at a given temperature is a constant value for any gas and any amount of any gas. If we change the volume, then the pressure will vary in such a way that product remains the same. If we change the temperature then we

Digitized by Google

get again a certain value which will not change except by a change of temperature. If we simply take account of the temperature, by dividing this product by the temperature, so many degrees from the freezing point of water, and then add the number 273 to it, we get the absolute temperature of the gas. Then we can write $pV/(273 + t) =$ constant.

This constant is simply proportional to the quantity of a gas; it is invariable for a given quantity of gas. If we know the quantity of gas, its volume, its pressure, its temperature, then, and divide the product of pressure and volume by the temperature, we get a constant number, the same for every temperature, pressure and volume; it is invariant. It is also an invariant for any given amount of a given gas, and it is of course proportional to the quantity of the gas. If we double the quantity of the gas, for example, in the same volume, the pressure will be double, and so on.

Therefore we can calculate this invariant for the amounts of different gases which are related as their molecular weights. What will turn out? Now, after our first assumption in molecular weights of different gases, there are like numbers of molecules from the hypothetical side, but the molecular weights of different gases mean such weights of different gases as are contained at the same temperature and pressure in the same volume. This means nothing else than if instead of an arbitrary quantity of different gases we take molecular weights expressed, for example, in grams, this invariant becomes a general invariant, the same for all gases, quite independent of their nature; and the law, which is an empirical law and which underlies the molecular hypothesis, means nothing else than if we compute the invariant for any gas in chemically comparable quantities, as expressed by this formula, we always get the same invariant, independent of the nature of the gas. You see it is a quite empirical fact. It means that the invariant of the gas is directly connected with its combining weight in such a way that for the combining weight of any gas is either equal to that for the combining weight of other gases, or is related in a simple way to it. In other words, if we express or formulate such quantities of different gases which stand in the most simple chemical relations according to this table, then we get such quantities as are possessed of the same value as gases.

This is the simple empirical fact which is connected with the idea of molecules and you see there is nothing about the small particles

Digitized by Google

doing something connected with this idea, it is simply a most general expression of the discovery of Gay-Lussac that gases unite in the simple ratios of their volume if observed at equal temperatures and equal pressures.

Now the physical meaning of the molecular theory is a thing which has not been accepted generally by chemistry. Our books are written still for the large part according to the conceptions of the molecular hypothesis, and there has been but a slight attempt to free these general facts from the arbitrary disguise of this hypothesis.

We shall now turn to some developments, or to some difficulties which have been vanquished with success, and to a new aspect only developed in the last fifteen or twenty years. The difficulties will be found first with acetic acid, sulphur and some other substance whose vapor density is too large to fit into this system of molecular weight. This is explained quite easily by the assumption that not only two — for example with sulphur — not only two atoms of sulphur unite to form the molecule of sulphur vapor, but three, and on this assumption the real vapor density of sulphur turned out quite correctly. Of course such assumptions can be made in every case when the real experimental density is larger than the density calculated from the general ideas of the molecular hypothesis.

But then another difficulty arose. It was connected mostly with the vapor density of ammonia salts — for example ammonium chloride, NH_4Cl, where the real vapor density is found to be half, or somewhat larger than half, the value represented by NH_4Cl. This can not be explained, of course, on this general assumption, because ammonium chloride yields results which are too low — not too high.

Then from three different sides the explanation was given that the vapor of ammonia chloride was not a real ammonium chloride, but consists of ammonia plus hydrogen chloride, *i. e.*, that ammonium chloride dissociates into its components when brought into the state of vapor. Of course this needed again experimental proof, and this experimental proof was brought about at that time by different means. It was not quite easy to prove it, but the experimenters were successful, and showed that if the vapor of ammonium chloride is made to diffuse through an asbestos septum, the ammonia gas goes very much more quickly through the septum

Digitized by Google

than the hydrogen chloride does, so that in this way it was proved that they had to do, not with pure gas as a chemical substance, but a gaseous solution consisting of two different gases, separated by this mechanical means from one another. Then the objection was brought forward that it was by the influence of septum that the separation is brought about. But if there were no ammonia vapor, for example, in the vapor of the ammonium chloride, there could be no possibility of separating the ammonia, for the separation was brought about by the quicker diffusion of ammonia, and the property of a substance not present at all could not influence the state of the whole system. Then by later experiments this objection was put aside experimentally, for the same result was obtained by the use of a septum of ammonium chloride. And finally it was shown to be possible, without any septum, to separate the two gases by free diffusion.

So it turned out that indeed it was quite reasonable, and experimentally without objection, to assume that the vapor decomposed into these two gases which formed the solution, a homogeneous mixture, and in our own time, about ten years ago, a series of proofs were concluded in a most remarkable way by Becker, in Manchester, who discovered that the presence of water changes very much the ratio of composition and union of the different gases. When he heated most carefully ammonia and hydrochloric acid in the absence of water, no precipitation of the chloride ensued; and the temperature remained much lower than the temperature when ammonium chloride is formed. On the other hand, if he vaporized dried ammonium chloride, he found just the expected volume of the gas, and this was because the water acts as a catalyzer — I will explain what that means later. Without the presence of water the decomposition of ammonium chloride is so slow that just the density of the undissociated vapor could be observed, and in this way the whole cycle of experimental proof was completed.

Now, there is another very important development of the same series of ideas directly related with this class of development. It had not a distant beginning; its birth can be dated back to 1885, when it was mentioned by the famous chemist, van't Hoff, who found an analogy between substance in solution and gasified matter. But van't Hoff was not the first; it had been discovered at a much earlier time by Pfeffer that there was a pressure in solutions quite comparable with pressures in gases, and that if we employ the

Digitized by Google

same formula for any dissolved substance as we do for gases, using as the volume of the gas the volume of the solution, and a certain pressure, which we call the osmotic pressure, for the gaseous pressure, we get the same invariant for dissolved substances as we do for gaseous substances, and therefore the law of gases may be extended from gases to any and every dissolved substance.

This was the most important enlargement of the law of Gay-Lussac, and it is worth while to spend a few minutes upon this development. It began with the work of two scientists, one a Frenchman named de Vries, and the other a German named Pfeffer, who were occupying themselves with studying the osmotic pressure. The facts were as follows: That it is possible to construct certain septa, to coat a porous cylinder with copper ferrocyanide in such a way that if we put in it a solution of sugar, pure water, exerting a pressure upon the walls of the cylinder, will go into the sugar solution. And the pressure developed by a substance in solution is proportional to the amount of substance present, and to the absolute temperature.

Pfeffer discovered only the existence of this pressure and its dependence upon temperature and concentration, but van't Hoff discovered that, if different solutions were prepared and the pressure computed according to the law of gases he got for the molecular weight of sugar, for example, the same pressure, if in the same volume, at the same temperature, as he would if the sugar were in the gaseous state.

If you construct a movable septum and place it between a solution and the pure solvent, it will be necessary to exert a pressure, to keep the septum in place, for otherwise the septum will move because the water will go into the solution and will thus exert a pressure upon it. It is necessary to keep the septum in place by some other pressure in order to get exactly the pressure called the osmotic pressure.

All the consequences which can be deduced from the law for gases can then be applied at once to dissolved substances. I will allude to only one of these consequences which will show itself as very important in our later investigations. If we investigate in this way a solution of potassium chloride we will find exactly the same difference as the chemists of the middle of the last century found with ammonium chloride, namely the expected pressure is doubled, and we have to divide the molecule of our potassium

Digitized by Google

chloride into two molecules to correspond with the facts. This is not to be explained by the general views of van't Hoff, but should be explained by what was developed by Arrhenius, by the investigation of the electrical conductivity of salt solutions. He was brought to his idea by observing that a part of his salts, ions as they are called, could not be considered as united, as bound together in a salt solution, but must be considered, as a consequence of the behavior of the conduction of electricity, as made up of independently moving substances, each of which can transport the charge of electricity, quite independent one of the other. Therefore he assumed that the solution of potassium chloride contains potassium and chlorine, of course not common potassium or common chlorine, but ions of these substances, differing from them by their relation to the analogy — I cannot dwell any more upon this question, but it was inevitable to assume from this electrical standpoint that the potassium and chlorine ions were free and independent from one another, and this fitted in with the theory of van't Hoff, that in solutions of potassium chloride, indeed, in solutions of every salt, a kind of dissociation must be assumed.

In this way by this development of the general idea the science of chemistry has developed by itself, and the entire portion of inorganic chemistry has been influenced by this development of theoretical ideas.

Fourth Lecture: Constitution and Isomerism (Organic Chemistry).

Ladies and Gentlemen: If you will recall the various cross-sections we have considered as drawn through the body of theoretical chemistry, you will remember at the same time that in our first cross-section we did not encounter hypothetical things or at least not those which could not be freed from hypothetical conditions and brought into a purely empirical form; but this became more and more difficult to do as the science progressed. Even the idea of a chemical substance or a chemical individual entirely free from hypothetical conditions, is somewhat connected with the hypothesis of atoms, but it was easy for us to show that this connection is only superficial, and that the purely empirical or scientific part of it could be investigated by itself.

Underlying the relations between the hypothetical and empirical portions is the idea of molecules, but even here it was possible to

Digitized by Google

recognize in Gay Lussac's law of the simple ratios of gaseous combinations, the empirical generalities as well as empirical laws underlying the hypothesis of molecules.

The part of chemistry which we shall investigate to-day cannot be presented in this way, as the former parts were. Organic chemistry is still so intimately interwoven and connected with hypothetical views that even to-day it seems indeed impossible to lay on the one side of the table the empirical facts in any satisfactory form and on the other side the hypothetical conditions. Therefore I can only give you the historical development as connected with hypothesis, and, at best, only some indications of the way in which the separation of facts and hypothesis may be carried out in the future.

The starting point of the question of isomerism and constitution was the general fact that different bodies or different substances are characterized by different properties, and at the same time are characterized by different composition. The tacit assumption, then, was that every body, every substance, has a definite composition of its own. Its composition depends on the one hand on the nature of the elements composing it; and, on the other, on the relation between the combining weights of these different elements. Every body has its own composition; a different composition means a different body, and the same composition means the same body.

This statement expresses the scientific knowledge of chemistry about the middle of the nineteenth century. Then a strange thing happened. You will remember that Berzelius used to collect all new discoveries, all new investigations in chemistry during one year and summarized them in his Jahresbericht. Then in one of his "Jahresbericht" it was stated that a young chemist named Woehler had investigated and analyzed a certain new acid and found its composition. On the other side, another young chemist named Liebig had investigated another substance, the acid of fulminating mercury, and had also carefully analyzed it.

It was a rather difficult task to analyze this substance, but he carried it out very successfully and thus found the composition of this acid and consequently, its formula. But as Berzelius remarked in his "Jahresbericht" both acids were of the same composition, although they had quite different properties. This seemed so impossible at that time that Berzelius at once attempted to find

Digitized by Google

the reason. . He assumed that some mistake had been made, for he could not believe that both analyses could be correct, and that two different substances could have the same composition, *i. e.*, were both composed of nitrogen, carbon, hydrogen and oxygen in the same ratio.

Liebig and Woehler, who did not know each other at this time, became angry at this, for everyone believed that the observations about the analyses were right and it certainly looked as if one of them was incorrect. They, therefore, arranged an interview, and this interview was the beginning of a most remarkable friendship which lasted through the lives of these great men. From that time science gained more by avoiding the friction which only develops useless heat, for energy is needed in the development of science and for the clearing up of some differences.

They repeated their analyses with the result that indeed both substances had the same composition, so there was nothing left for them to do but to accept this new and unexpected fact of science, that it is possible for two substances to have the same composition and at the same time utterly different properties.

From quite another side, then, from a scientist of the highest rank, a new instance of such a case was discovered. This was Faraday, who discovered the same fact in a rather unexpected way. At that time illuminating gas was just being introduced in Berlin, but the gas was not sent through pipes laid in the streets as now, but was compressed in copper cylinders and brought from house to house, just as beer or any other liquid. This cylinder was connected with the user's pipe system and the gas was used as long as it lasted. Now the company that was making and distributing this gas was much annoyed by the fact that liquids separated out in the cylinder of compressed gas and decreased the lighting power. Some of this liquid was sent to Faraday, that he might investigate, and, if possible, devise some means by which the trouble could be avoided.

Faraday investigated this liquid. I cannot tell what he found, but would only like to mention that he, among other things, found benzene, and that this was an independent discovery of benzene. for it had been first discovered in quite another way. But at the same time he found that one part of the liquid was very volatile with a boiling point of 20 to 29 degrees centigrade, and had the same composition as the well known ethylene, a gas which was obtained

Digitized by Google

from alcohol by distillation with a large amount of sulphuric acid, Not only the vapor density of this liquid, which we now call butylene, but the composition also was exactly like ethylene. The former has a formula C_4H_8, the latter C_2H_4.

This was another instance, and Berzelius finally agreed that it was indeed possible to have different substances with the same composition.

Then another instance was found in quite another field. This was where large works for the manufacture of tartaric acid had been established. They transformed the potassium salt into tartaric acid, but from time to time they obtained instead of the well-known acid another substance, which had another crystalline form, and crystallized with water (where generally tartaric acid does not contain water of crystallization), but had otherwise the same composition, the same taste, and formed salts in the same way, or a very similar way as tartaric acid.

In this case Berzelius had an opportunity to investigate the matter for himself. He got a specimen of this newly discovered acid, prepared a number of its salts, and finally established the fact by very careful analyses, that this new acid was indeed different from the well-known tartaric acid in some respects, but was very like it in the way it formed salts, and had exactly the same composition. The salts also were similar to the salts of tartaric acid, so that a new case of two substances of different properties but of the same composition was at hand.

Then Berzelius felt it very necessary that science acknowledge and recognize this fact, and so he brought it into the general possession of science by a process which looks rather superficial, but which is of the utmost importance, by giving a name to the general fact. He designated the general fact, that the substances of equal composition could possess different properties by the name "isomerism," and called such substances as have different properties, although the very same composition, "isomeric substances."

Now, it seems a very small thing to give a name to such a thing. Everyone or anyone could do it; and it looks as if there was no progress connected with the giving of the name. Nevertheless it has proven that this name was of the most beneficial influence on the development of chemistry. Finally, these facts were brought in order, and found their place in the system, and all facts of the same kind were simply put upon the same shelf and considered as new cases of the well known and general fact.

Digitized by Google

Such is the effect of the invention of a name; the recognition that there is a new scientific concept to be formed, a new law to be acknowledged and pointed out, and that the concept must be designated by an appropriate name. Everything which has a name has been before a concept, and has been named simply that we may handle it in a convenient way. So it was a great piece of work of Berzelius to recognize that a new concept, a new general law must be formed. The name reminds us then of the existence of the law, and makes it easy to handle and use it for general scientific purposes.

From this time the number of substances which were found to be isomeric increased more and more, until now, as you know, they can be counted by the thousands and even by the hundreds of thousands. They are, of course, only possible substances; they are not real substances, because chemists do not find time and have not interest enough to prepare them, but with higher derivatives of hydrocarbons in the series of 20 to 30, the number of possible substances is indeed overwhelming, and in the same way somewhat complex, as every chemist working in organic chemistry knows.

Now it is quite a different question to explain such a law. Of course as the fact exists it has to be dealt with, and there are many questions and many explanations. But explanation has nothing to do with the possibility of such a fact. It is simply a question of how to connect such a fact with other known facts. When we find a connection to other facts which we have known for a more or less long time, we call the establishment of the connection an explanation. If we know one man and then he brings his brother, the fact that this new man is the brother of our acquaintance will explain to us the new man; but if we know the brother beforehand, the other man is to be explained as the brother of our old friend. In this way it depends entirely upon the historical development of science what we are to call an explanation. An explanation in this case means only that a connection exists between this new fact of possible differences of properties connected with the same composition, and many other facts in science.

Now this simple and direct experimental form of explanation was not tried when science first heard of this new fact, but quite another kind of explanation was given, namely, a hypothetical

Digitized by Google

one. You will remember that not only Berzelius, but all chemists of his time were convinced of the truth of the atomic hypothesis; they did not regard it as a hypothesis at all, but as a fact, just as the fact of combining weights, for example. Science was not developed sufficiently to distinguish sharply between hypothesis and facts, and so the question of explanation or connection had quite another meaning. Instead of seeking for a connection between this new fact and the older ones, they inquired as to the connections between this new fact and the old hypothesis of the atomic structure of compound substances. This was a mistake I am firmly convinced, and was in every case following a sidepath, but this sidepath is the one chemistry has followed since that time. It is with much reluctance then, that we must relinquish a purely experimental method, and follow chemistry along this side path on these questions and ascertain the connection between this new fact and the hypothetical assumption of atoms.

Now, if we regard a combined substance as composed of atoms of a peculiar kind — every element having atoms of its own — then in combined substances, since they are composed of the atoms of the different elements of which the substance is composed, we should expect of course the property of the compound to be dependent upon the properties of the constituent elements. Now, with one property we know that it is so; the weight of any compound is exactly equal to the sum of the weights of the elements which have reacted to form the substance; but with other properties it is not so. For example, from the yellow sulphur and white or grayish lead, we get a brownish black compound, sulphide of lead. And in the same way we might cite thousands upon thousands of examples in which the properties of the compound substance are not the sum or the average of the properties of the elements composing it.

In addition to this we know that elements are often endowed with the property of assuming different forms; carbon, for example, can appear as charcoal, graphite or amorphous carbon, and if the atoms of carbon unite with atoms of, say, hydrogen, we cannot foresee whether we are to expect the properties of the diamond or of charcoal in the combination. Of course, as a matter of fact, we do not expect any of these properties, for the properties of the compound have nothing to do with the kind of carbon, but are entirely different.

Digitized by Google

In such a way as this, so far as I know, the question why the properties of compound substances are so different from the properties of the combining elements has never been asked. It was taken simply as a fact (and the atomic hypothesis prevented further inquiry, although it was not in accord with the fact) and attempts to account for it were made only in a superficial way. The motions of the atoms *may* be different in the compound from their motions in the elements, and therefore the properties *may* turn out different, *but*, as you will see, we do not *know* anything about it. We have no assured notions about the motion of the atoms in the elements; no notion at all of the motion of the atoms in a compound substance. All these relations still lie in utter darkness and form, indeed, the contradictions and unsolved problems of the atomic theory.

Nevertheless the question of isomerism, of atomic changes, was investigated at once, and Berzelius was the first to offer a possible way of understanding the existing differences. You will find in one of his Jahresbericht a very extended consideration and explanation of the possible differences of isomeric substances, and indeed the idea he presented there has been the leading one in the entire later development of the science. Berzelius explained that it was possible to arrange the different atoms constituting any compound substance in very different ways; therefore one could expect as many different types as there were numbers of different kinds of compounds, *i. e.*, as there were different ways of arranging the given atoms of the compound substance. Therefore he introduced the idea of the mutual arrangement of the relation of the several atoms forming a compound substance, and he gave a picture of how he presented to himself these possibilities. He indeed pointed out at the end of his consideration that his pictures, which were drawn on paper, were not at all exhaustive; that it was possible that the different atoms could be arranged in different ways and spaces. From these different space arrangements arose new possibilities of different properties, *i. e.*, new possibilities of arrangements. Therefore Berzelius even considered the possibilities of space arrangement of atoms or stereo-chemistry, as it is called in our day. This kind of an explanation seemed to chemists entirely satisfactory, and the whole development of organic chemistry to its present form is dependent upon this one idea of Berzelius. Only the question of arrangement, or the question of

Digitized by Google

what he should understand by arrangement was answered in a different way, and what is called the development of organic chemistry is nothing else than the trial of different views, or general representations of possible arrangement of the atoms in space. These different arrangements, which we know as radicals or types, are nothing else than the result of trials to obtain mental pictures, *i. e.*, hypothetical pictures of the atoms of substances with different properties having the same numerical relations between the chemical elements.

At first the theory of radicals was developed. It was developed from one of the well-known facts of inorganic chemistry. In organic chemistry, even then, it was very well known that ammonium could act just as potassium or sodium does. Salts of ammonium were of the same shape and same crystalline form as salts of potassium, and it was known that the complex NH_4 would replace the element potassium in various compounds producing similar compounds.

Radicals, thus, were designated as complexes of different elements which could act in the same way as elements, as far as concerns combination. Further by the masterly work of Gay Lussac, it was proven that cyanogen, again a compound substance, was endowed with the same properties in this respect as the halogen elements, chlorine, bromine, and iodine.

Therefore the idea of a radical as a certain complex which could act as an element toward other elements or radical combinations, was already developed in inorganic chemistry, and the first step in this direction for organic chemistry was nothing but an application of the idea of radicals to organic compounds.

Thus Berzelius was almost the promoter of this theory which seemed to be confirmed in a brilliant way by the general investigation by Liebig and Woehler on the compounds of benzoyl. Liebig and Woehler worked together at first. Woehler two years before had lost his young wife and in order to console him and to take him away from his worry, Liebig invited him to come over to visit him at Esson and to work with him. They began to work accidentally with the oil of bitter almonds but of course they could not finish the work in the short time that they were together, but they began the work and then carried it out during several years. Thus Woehler would prepare the new substances from the oil of bitter almonds and send them to Liebig who

Digitized by Google

analyzed them and tried to ascertain the connection between the different substances and the starting compound, which was quite a scientific investigation. The publication of this investigation was the turning point for organic chemistry, for by these different investigations it was known for the first time that a number of different substances could be obtained from one substance as a starting point; in other words, that there were a number of different compounds which could be arranged as the members of a family around a certain radical, which was to be recognized and found again in every member of this family. This radical is the substance C_6H_5CO, which is called benzoyl.

It is thus possible to find such families of closely related substances, and as you will remember, even up to this time the investigations of organic chemistry have remained the same; every chemist investigating any compound of organic chemistry works in this way. He starts from such a substance and tries to make as many derivatives of it as possible, in order to find its true position in organic chemistry.

To Berzelius belongs the greatest praise for this. He proposed to call these things by certain names just to indicate that a new development of chemistry was the result of this discovery. He proved his good judgment in this (Berzelius was the truest scientist I have ever met in my historical investigation), and at the present time, the theory of radicals seems to be so well established that no change at all is necessary.

Then appeared another piece of work by Bunsen, who combined potassium acetate and arsenic trioxide, and it is almost incredible to look into Bunsen's work and see what difficulties and dangers he had to overcome in carrying out this investigation. This substance cacodyl does not only smell horridly, but is poisonous to a degree, and in addition takes fire spontaneously when in contact with the air. This is just the kind of work Bunsen liked, where difficulties were to be overcome, and he threw himself with delight into this most difficult work. He lost one eye during the work, but this did not stop him. After recovery he continued. He was almost killed by a little quantity of cacodyl cyanide, the most poisonous substance of the whole series, lying between life and death for several days. But after recovery he continued his work, and prepared and analyzed quite a number of derivatives of this terrible substance. Then, by the way, Bunsen left organic chem-

Digitized by Google

istry altogether. Such a simple thing as the substances of organic chemistry did not interest him at all, and he found his field in quite another place.

Now, by this work the theory of radicals seemed again to be established in the best way, but later a danger came up from quite another side. It was the discovery by several investigators that chlorine acts upon organic compounds in a very peculiar way, throwing out the hydrogen and settling itself in its place. For example, Dumas discovered that if he brought bottles filled with chlorine and pure acetic acid in the sunlight, beautiful crystals developed on the glass in a short time, and that fumes of hydrochloric acid were evolved when the bottle was opened. The crystals proved to be of an acid, the very well known tri-chloracetic-acid, the composition of which is CCl_3COOH.

Now Dumas explained that we have here a substance in which hydrogen has been replaced by chlorine. But Berzelius rejected this view with all his force. For Berzelius had developed a theory of chemical combination according to which every atom was endowed with certain powers, combination being due to the mutual attraction of electrified atoms. Since in his system chlorine was a very strongly negatively charged atom, while hydrogen was a strongly positive substance, it is impossible from this standpoint that a positive atom could be replaced by the strongly negative ones, otherwise, the whole structure of attraction would be destroyed; Berzelius therefore simply explained this contradiction of the electro-chemical theory of combination by saying that Dumas' theory could not be true.

Dumas at first was not daring enough to uphold his point, but explained from his side that although he would not think of a direct replacement of the hydrogen by chlorine, no one could deny that such an action took place. Then, from the other side, a large number of experiments were made, especially by a French chemist, who investigated the action of chlorine on hydrocarbons and napthalene and found it was possible to replace one by one the different atoms of hydrogen by chlorine, and get quite a number of derivatives, until all the hydrogen had been replaced by the chlorine. Then it was impossible to doubt that chlorine could take the place of hydrogen, and science had to acknowledge the fact. At this Dumas also became courageous and upheld the same view, and even claimed more than this. And, in fact, every day brought

Digitized by Google

some instance where the hydrogen of substances was replaced by chlorine or bromine or other negative substances.

Berzelius, however, who was a rather old man, fought with his whole energy against this. And finally, as he could not deny the facts altogether, he invented a rather complicated theory of radicals and thus explained these substances. He wrote the formula as a double number of atoms. He considered both substances as derivatives of oxalic acid, and this was connected with something behind or back of oxalic acid.

Now you see it was the theory of substitution. Berzelius tried still to uphold his view, but, as I explained to you some time ago, science went over his head and he could not do anything else than complain about the wrong way which science had taken, according to his opinion.

Thus the theory of substitution was developed and as an outcome of that theory arose the question, what things can be substituted for others? And what things can enter, one for the other, into chemical compounds? Of course, I can not try to develop the whole history of chemical theories.

Finally, the radical theory took form. Every substance can be considered as a derivative of another; *i. e.*, by the substitution of one atom for another.

And at length it was concluded that the idea of substitution extended to almost anything. Anything which could exist for itself in organic chemistry became then a mono-valent radical if one atom of hydrogen could be taken out of a compound and replaced by the radical.

The most important thing in this line was the discovery of carbon compounds and the fact that they could be recognized as the derivatives. With the more complicated compounds, in this way, we could get a better representation of real facts. It was found then that two or more atoms of carbon can unite with one another by using one valence, although there are other combinations in which two or even three valences of carbon were used.

All these developments went on in two dimensions on paper, and all new derivatives were described by such a different constitution as could be expressed by the various possible linkings of the atoms in two dimensions.

Then isomerides were discovered which did not fit into this theory, and it is most interesting to observe how, for example, in the

Digitized by Google

middle of the last century, in the more complete text-books, *i. e.*, those in which every known substance is mentioned, these isomeric substances were collected in an appendix attached to the different chapters and treated as something which nobody liked to speak much about, and which were only included for the sake of completeness, even though they were a disgrace to the beautiful structure of organic chemistry.

Finally one able man, or two at the same time, came, who took upon themselves the task of trying to convince the world that at least all those substances had their existence as peculiar substances, and so, just as other things, should find their place in the system of organic chemistry; and that it was proper to develop the subject in such a way that even these substances could find a proper place. These men were van't Hoff, in Amsterdam, and a Frenchman, Le Bell, This theory was that the face of the paper was not sufficient upon which to arrange the atoms in their proper mutual arrangement. It is necessary to consider a three-dimensional space to arrange them; therefore, a structure of chemistry of two dimensions was changed into a structure of three dimensions, and stereo-chemistry arose. It was not only possible now to house the structures of former times in the new structure, but possibly also to find out some most important relations between constitution and the various physical properties, especially the relation of a certain kind of constitution, as expressed by these structural formulæ in space and by optical facts. Such stereo-chemistry could furnish, indeed, an admirable linking between the different bodies and their physical properties, and give an admirable picture of their development.

Now only in the later times another fact has been discovered which is treated in just the same way as I have described for the superfluous isomerides of spatial chemistry. This followed a discovery by Walden. The general fact is that every rotating substance exists in two states, as dextro-rotary and lævo-rotary. Now, if we start from the right malic acid, the dextro, and replace the hydrogen by chlorine, we also get a certain active mono-chlor acid, but now if we replace this chlorine again by the hydrogen and get back malic acid, we find that this malic acid is not right, but left. Then, if we once more replace the hydrogen by chlorine, and come back again to the mono-chlor acid, we get by this double process our starting point, *i. e.*, our original malic acid. This cannot be explained, as far as I can see, by Fischer's

Digitized by Google

theory of stereo-chemistry, for that provides that if we replace the hydrogen by chlorine and then replace the hydrogen, we should get the same acid having the same rotatory power, and not the opposite acid. Therefore this kind of substitution cannot be represented by spatial relations, we need a double turning point to get our first place, but spatial relations only require a single turning to get back to the former place. There is an investigation of Reimann's in which he speaks of a surface called the Reimann surface, which has this property, *i. e.*, if you trace a circle on the surface, you must start at one side and go to the lower side and revolve it twice to get again to the same point on the upper side. Just so it seems that the malic acid behaves, and therefore it looks as if it were impossible to represent or depict the actual behavior of active substances by *any* spatial arrangement. We require a space which is endowed with other properties than our general space.

Soon three dimensions may not be sufficient, and then the question arises, what now? More than three dimensions we can not give to the atoms if we want to keep the atoms, and this leads us to the general question: Can we not get rid of all these methods of depicting compounds by the interposition of atoms; can we not find out some possible theory of organic chemistry which is free from all these hypothetical assumptions and which is simply a description of real facts just as I have tried to show you that it is possible to describe and connect the law of combining weights and the laws underlying the molecular theory with real facts, without the help of hypothesis?

I think it is possible, but it would be an enormous task, and would take a young man who has still his entire life potential to exert, for this will be a very large and difficult piece of work.

The question of the constitution in organic chemistry is generally spoken of as the question of existing types or variety. Take for example the benzene question: For the substitution of one hydrogen atom of benzene we get only one derivative, quite independent of the way in which we make the substitution, and of what hydrogen is replaced, to speak in the most picturesque way. After the substitution of double the combining weights of hydrogen by something, chlorine, for example, we obtain three different isomeric substances, and we find that there are only three kinds possible. Therefore if with these substitutions in benzene we get a treble variety, we can simply describe the fact and the whole

Digitized by Google

problem can be put in this quite simple mathematical way. After finding the types or varieties by such or such process of substitution, we can form a table of existing varieties and find some general expression, some mathematical formula to express it. I do not know if I make clear enough my idea, but I think it is possible indeed to deal with the question in a purely experimental way. It is an experimental fact that there exist three compounds of chlorine and benzene and their substitution by another element will result in only three isomeric compounds and no more. By just expressing these experimental facts, it seems to me we get the same result, and freed at the same time from all hypotheses; we would be dealing with facts alone.

I can only repeat that I think it would take much work to carry out this idea, *i. e.*, to develop it so far as to cover all our actual knowledge of organic chemistry, but I feel rather sure that something in this line, free from all hypothesis, could be developed. And that by it we could substitute for hypothetical organic chemistry a rational one, unsaturated with this discussion of the theory of atoms. You know of course, that the whole difficulty is how to account for the fourth valence; for the fourth valence of carbon is indeed a nuisance. If we could get rid of it, all would be in good order, all discussion would cease at once. Then we could say — such and such a variety is brought about by such and such a chemical change.

Sections V. and VI. will appear in the next number of the QUARTERLY.

Digitized by Google

THE DETERMINATION OF MINERALS IN CRUSHED FRAGMENTS BY MEANS OF THE POLARIZING MICROSCOPE.

By

AUSTIN F. ROGERS.

Our knowledge of the optical characters of minerals is confined almost entirely to the following classes of minerals: (1) Rock-forming minerals, of which many detailed characters useful in identification are known. (2) In oriented sections of nearly all transparent minerals the optical constants, index of refraction, axial angle, etc., have been determined. I believe it is also possible to use the detailed optical and microscopic characters of the non-rock-forming minerals in identification as well. The polarizing microscope should have a place in every mineralogical laboratory and supplement the blowpipe in the determination of minerals.

While preparing cleavage plates of minerals to illustrate for class use some of the optical characters of crystals, it occurred to the writer that possibly minerals might be determined in crushed fragments by means of the polarizing microscope. The results obtained in the last year or so have more than exceeded my expectations.

The method in general consists in reducing the mineral to coarse powder* and examining the fragments on the stage of a polarizing microscope. The powder is placed on a glass slip, the coarse fragments removed by tapping the slip with the finger, then tapping off the medium-sized ones on to another slip. Some liquid, such as oil of cloves or bromoform is added and the shape, color, index of refraction, extinction, elongation, specific gravity, etc., determined. The remaining fine powder is tested as to solubility, and if soluble microchemical tests are employed.

The orientation is not haphazard as in rock sections. Because of cleavage there is in many cases a constancy in orientation. For example, in ten fragments of hornblende the extinction angles only varied from 15½° to 17½°.

Even if the method is not used in the identification of minerals

* A small square anvil and blowpipe hammer are convenient. Pounding gives better results than grinding as the fine particles adhere to the larger fragments and render them somewhat opaque.

Digitized by Google

it furnishes a convenient method of illustrating the optical characters of minerals without the use of thin sections which are rather expensive when required for large classes.

In a general course in mineralogy some attention ought to be paid to the optical side and every student should know something of the meaning of such terms as pleochroism, index of refraction, extinction angle, etc. (as an introduction to petrography, if for no other reason). With this end in view, the following suggested outline has been prepared. It serves the double purpose of furnishing a convenient method of studying the optical characters of minerals and as an introduction to the use of the scheme, as the slides may all be made from crushed fragments or cleavages.

SUGGESTED OUTLINE OF SLIDES TO ILLUSTRATE THE OPTICAL PROPERTIES OF MINERALS.

Ordinary Microscope, Common Light. (Both nicols out,* medium power objective.)

Form.

Calamine crystal (measure angles).
Alunite crystal.
Cleavage fragments.
Triangular — fluorite.
Rectangular — anhydrite.
Prismatic — actinolite, aragonite.
Acicular — wollastonite, pectolite.
Flat plates — orthoclase, colemanite.
Irregular — quartz, apatite.

Inclusions.

Irregular in topaz.
Regular in phlogopite — labradorite.
Schiller structure — hypersthene.

Index of refraction (Becke test) and relief.

High relief, $n <$ balsam — fluorite.
Low relief, $n =$ balsam — orthoclase.
High relief, $n <$ balsam — garnet, anhydrite.

Polarizing Microscope, Polarized Light. (Lower nicol in, medium power objective.

Pleochroism.

Pink to red — erythrite.
Blue to purple — glaucophane.
Pink to greenish — hypersthene.

Index of refraction varies with direction — calcite, aragonite.

Crossed Nicols, Parallel Light. (Both nicols in, medium power objective.)

Isotropic.

Amorphous — opal.
Isometric — fluorite, garnet.

* For most purposes the lower nicol may be left in.

Digitized by Google

Uniform illumination — pyroxene (parting ‖ 001).

Anisotropic — anhydrite, gypsum, colemanite, etc.

Interference colors.

Gypsum wedge † — make color chart.
Low-order colors — apatite, beryl.
Bright colors — barite, anhydrite.
High-order colors — calcite, dolomite.

Extinction.

Parallel — aragonite, calamine.
Symmetrical — calcite, dolomite.
Oblique — gypsum, pyroxene, amphibole.

Elongation.

Parallel to faster ray (a') — stilbite, ægirite.
Parallel to slower ray (c') — wavellite, amphibole.

Aggregate structure — chrysocolla, serpentine.

Optical anomalies — leucite, analcite.

Twinning.

Simple — gypsum.
Polysynthetic — plagioclases.
Crossed — microcline.

Crossed Nicols and Convergent Light. (Both nicols in, high power objective, condenser and Bertrand lens in.)

Interference figures.

Uniaxial positive.
Alunite crystals.
Brucite cleavage.
Uniaxial negative.
Calcite, basal parting.
Wulfenite, tabular crystals.
Biaxial positive, small axial angle.
Clinochlore cleavage.
Biaxial positive, large axial angle.
Topaz and heulandite cleavages.
Biaxial negative, small axial angle.
Biotite, phlogopite and talc cleavages.
Biaxial negative, large axial angle.
Muscovite, lepidolite, margarite and cyanite cleavages.
Biaxial, ⊥ to optic axis, showing axial bar.
Pyroxene, basal parting (‖ 001).
Epidote, basal cleavage (‖ 001).

Form is due to cleavage, and is fairly constant. The fragments, of course, lie on the broadest surfaces. One can easily distinguish seven groups, designated by Roman numerals.

† Can easily be made by shaving down a cleavage flake and cutting away part of the under side.

Digitized by Google

I. Triangular plates.
II. Square or rectangular plates.
III. Rhombic plates
IV. Prismatic plates with uneven ends, more or less striated.
V. Very long fragments grading into needles.
VI. Flat plates not belonging to foregoing, rhomboidal or irregular in cross section.
VII. Irregular, but not plates, as shown by non-uniformity of interference colors.

IV. and VII. are the large groups.

Some minerals fall in two or three divisions. For example, gypsum is found in IV., V and VI.

Index of Refraction. — This, one of the most important characters of minerals, is easily determined by means of the so-called "Becke test." * The fragments to be tested are embedded in various liquids of known refractive indices. Focus sharply on edge of a thin fragment with lower nicol down and raise objective slightly when a bright line appears on the side of the substance having the greater index of refraction. For instance, if quartz is embedded in Canada balsam, and the objective is raised, the bright line appears on the side of the quartz, its refractive index being greater than that of balsam.

Twenty or more liquids might be used, but in this study it was found that seven were all that are ordinarily needed, and in many cases three suffice.

1.50 Benzol.
1.54 Oil of cloves.
1.58 Bromoform.
1.62 Mono-iodo-benzene.
1.65 α-monobromnaphthalin.
1.74 Methylene iodide.
1.83 Sulphur in methylene iodide.

If permanent slides are wanted, Canada balsam in xylol, with index of refraction about equal to oil of cloves, is used. Bromoform is perhaps the best liquid to start with. Determine whether index of refraction (designated by letter n) is higher or lower, then try liquid next above or below bromoform, and so on until n is known within certain limits.

* Becke, *Sits. der k. k. Akad. d. Wiss. Wien.*, I. Abt., p. 358, 1893. Abstract by Luquer; SCH. MIN. QUAR., 23: 127, 1902. Also in Minerals in Rock Sections, 2d edit., 1905.

Digitized by Google

In case of minerals of very strong double refraction, the refractive index varies with direction. For example, calcite, when the short diagonal of the rhomb is parallel to the plane of vibration of the lower nicol, has index of refraction less than that of bromoform, but when the long diagonal of the rhomb is parallel to the plane of vibration of the lower nicol it has index of refraction equal to that of monobromnaphthalin.

Color and Pleochroism. — Many colored minerals are colorless in small fragments, but some as malachite and azurite are practically the color of the hand specimen. Some of the colored minerals are pleochroic.

Interference colors depend upon thickness, and this in general varies with the size of the fragment. So certain sized fragments must be taken in determining interference colors, and the coarser fragments that pass through a 100-mesh sieve are selected. For the rock-forming minerals the colors are the same as for thin sections of about 0.03 to 0.04 mm. thickness. In practice it is hardly necessary to size the fragments. After a little practice one easily judges the size. It is not found practicable to distinguish more than three groups of interference colors: low order colors, bright colors and high order colors.

Extinction Angle. — The extinction angle is rather constant, much more so than in rock sections.

Elongation. — Besides the usual method, which except after some practice necessitates the use of the color chart, the following may be used. When the band of colors on the edge moves out, similar axes are superposed, and, when the band of colors moves in, dissimilar axes are superposed.

Interference Figures. — It is only occasionally that satisfactory interference figures can be obtained from fragments. But for the minerals with eminent cleavage the interference figure is the principal guide in identification.

Specific Gravity. — Several of the liquids mentioned under index of refraction, mono-iodo-benzene with specific gravity of 1.8, bromoform, sp. gr. 2.8, and methylene iodide, sp. gr. 3.3, are valuable for obtaining the specific gravity. The powder is dropped on a large drop of liquid. There will always be particles on the surface because of surface tension, but if the mineral is lighter than the liquid it will float, if heavier it will sink. This can de determined by focusing on top of the drop and then focusing downwards to the level of the glass slip.

Digitized by Google

Solubility. — Water and the three acids, HCl, HNO_3 and H_2SO_4, are used in determining the solubility. Only dilute acids are used and always in the cold. Concentrated and hot acids are corrosive and injure the stage of the microscope. Then, besides, it is difficult to control the concentration if strong or hot acids are employed.

The solubility of a mineral is judged in several ways: (1) By the rounding of the sharp edges (2) by the formation of a jelly in the case of some silicates (3) by the deposition of crystals on the edge of the solution. The interference colors of flat fragments do not change appreciably during solution for the attack is principally along the edges. For carbonates it is often necessary to heap up the mineral in a little pile before the bubbles of CO_2 can be detected.

Microchemical Tests. — As far as the writer's observations go, a general method of microchemical analysis is only of use in the hands of the expert, but some of the tests are of decided value and easily applied.

In some cases evaporation of the solution serves as a microchemical test. For example, a solution of witherite in HCl deposits characteristic crystals of $BaCl_2$ (Fig. 1) and as this is only barium mineral soluble in acid it serves as a microchemical test for barium. Nitric acid solutions of lead minerals deposit octahedral crystals of lead nitrate (like kalinite, Plate I.), which serves as a test for lead.

The reagents employed, in addition to the acids mentioned, are as follows: Salt of phosphorus (S.Ph.), which in presence of NH_4OH

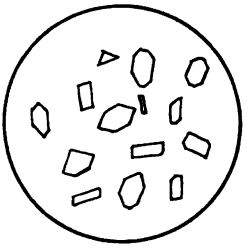


FIG. 1.

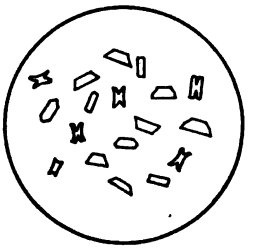


FIG. 2.

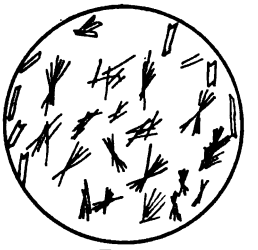


FIG. 3.

gives in magnesium solutions the characteristic hemimorphic crystals of microchemical struvite (Fig. 2) in concentrated solutions, twins. $(NH_4)_2MoO_4$, which gives a yellow precipitate to nitric acid solutions of phosphates. $AgNO_3$, which gives a white

Digitized by Google

precipitate with chlorids soluble in NH_4OH and redeposits octahedral crystals. A knife-blade touched to copper solutions is coated with metallic copper. H_2SO_4 with calcium solutions gives microchemical gypsum (Fig. 3) and this is perhaps the best and simplest test for calcium, far better than the flame test. By reversing this and using calcite in presence of HCl or HNO_3 sulfates may be tested for.

Determinative Tables. — The determination of the more common minerals that are fairly transparent in fragments has been made the objective point and accordingly several determinative tables have been prepared.

For minerals soluble in water the best and simplest method is to recrystallize from the water solution by allowing several drops of the solution to evaporate in the air on a glass slip. The recrystallized product is very characteristic, either being the original substance or different substances. For example carnallite, $KMgCl_3 \cdot 6H_2O$, on recrystallizing gives KCl, $KMgCl_3$, and $MgCl_2$ in order named. For these minerals, Plate I. may be used as a determinative table.

For minerals with eminent cleavage in one direction, which cannot be crushed, the list of minerals giving interference figures, page 315, may be used. (Micaceous minerals of the text.)

But for the greater majority of minerals the crushed fragments are prepared and the table following page 331 used. As the result of experience the shape of the fragments is taken as the main divisions of the scheme. The seven shapes mentioned on page 316 are those used. The other characters are of unequal importance. It may be the pleochroism, color, interference color, etc.

The table on page 331, minerals arranged according to their indices of refraction with respect to the seven liquids, will be found useful in "running down" the mineral still closer and also in determining the mineral when the other table fails to locate it.

Remarks. — The writer fully realizes the objections and limitations to the method as here developed and can only hope that it may be improved with use. It is intended to supplement, not supplant, other methods. It is not as general as a blow-pipe method for it requires the use of a microscope and is limited to minerals that are fairly transparent. A few minerals as barite and celestite, chrysoberyl and corundum cannot be distinguished from each other. The determination is very exact in minerals soluble in water or

Digitized by Google

in acids when microchemical tests may be applied. Some tests are more exact and far easier to apply than blow-pipe tests.

At any rate in using the method the student's attention will be directed to the existence and value of the optical side of mineralogy and in some cases at least he can make use of it in determining minerals. (For example in distinguishing quartz and opal, amphibole and pyroxene.)

Alphabetic List of Minerals with their Microscopic and Optical Characters as Observed with the Polarizing Microscope.

Ægirite, IV. — Pleochroic, yellowish-green to bright-green. n(|| elongation) > methylene iodide < sulfur in methylene iodide; n(⊥ elongation) > sulfur in methylene iodide. Bright interference colors. Extinction angle small, 0 to 5°. Elongation || a' (dist. from amphibole).

Albite, VI. — Plates, rectangular, rhombic or irregular in outline. Often cloudy. $n <$ benzol; $n <$ oil of cloves. Low interference colors. Extinction 4° on 001, 19½° on 010. Direction of best cleavage || a'. Sometimes polysynthetic twinning.

Alunite, I.–VII. — Some roughly triangular, but mostly irregular. $n >$ oil of cloves, < bromoform. Triangular fragments dark between crossed nicols. Positive uniaxial interference figure. Others, bright interference colors. Insoluble in HCl. Soluble in H_2SO_4.

Alunogen. — (Recrystallized, Plate I.) Feathery radiated aggregates. Low interference colors. Parallel extinction.

Amblygonite, VI. — Mostly irregular plates but some rectangular. Cloudy. $n >$ oil of cloves, < bromoform. Bright interference colors. Polysynthetic twinning common. Elongation of twinning direction || a'. Resembles feldspars.

Amphibole, IV. — Colorless to green. Usually pleochroic. (Yellow-green to bluish-green.) n (usually) > monoiodobenzene, < monobromnaphthalin. Bright interference colors. Oblique extinction usually 10 to 20°. Elongation || c'.

Analcite, VII. — Glassy. $n <$ benzol. Isotropic or low-order interference colors or both. Gelatinizes with HCl and isotropic cubes of NaCl deposited.

Andalusite, VII. — Low interference colors. $n >$ monoiodobenzene, < monobromnaphthalin.

Digitized by Google

Anglesite, VII. — Mostly irregular but occasional rhomboidal (symmetrical extinction) or rectangular (|| extinction). $n >$ sulfur in methylene iodide. Bright interference colors. Insoluble.

Anhydrite, II. — Squares or rectangles. $n >$ oil of cloves, $<$ bromoform. Parallel extinction. Bright interference colors. Twinning striations || to diagonal of rectangles [tw. pl. (101)]. Occasional fragments show biaxial interference figure. Soluble in HCl and microchemical gypsum (Fig. 3), forms even without H_2SO_4.

Apatite, VII. — $n >$ monoiodobenzene; $n <$ monobromnaphthalin. Low interference colors. Soluble in HNO_3. $(NH_4)_2MoO_4$ gives yellow precipitate. Slight precipitate with $AgNO_3$. H_2SO_4 gives microchemical gypsum.

Apophyllite, II. — $n >$ oil of cloves $<$ bromoform. Squares and rectangles, isotropic with positive uniaxial interference figure. Rectangles, low interference colors with parallel extinction. Gelatinized with HCl, giving lumps of jelly.

Aragonite, IV. — n(|| elongation) $>$ monoiodobenzene, $<$ monobromnaphthalin; n($\perp$ elongation) $>$ monobromnaphthalin, $<$ methylene iodide. High-order interference colors. Parallel extinction elongation || a'. $G = 2.9$, so floats on methylene iodide (distinct from strontianite and witherite). Effervesces in HCl. H_2SO_4 gives microchemical gypsum.

Atacamite, IV. — Green. n(|| elongation) $>$ monobromnaphthalin, $<$ methylene iodide; n($\perp$ elongation) $>$ sulfur in methylene iodide. Parallel extinction. Elongation || c'. Soluble in HNO_3. Knife-blade coated with copper. $AgNO_3$ gives white precipitate. AgCl, soluble in NH_4OH.

Azurite, VII. — (But some elongate ones with || extinction and elongation || a'.) Blue color. $n >$ sulfur in methylene iodide. Effervesces in HCl, and needles of CuCl (?) crystallize out, copper deposited on knife-blade.

Barite, II., III., VII. — Rectangular, rhombic or irregular. $n <$ monoiodobenzene; $n <$ monobromnaphthelin. Bright interference colors. Parallel and symmetrical extinction. Elongation mostly || a'.

Beryl, VII. — Irregular. $n >$ oil of cloves, $<$ bromoform. Low interference colors.

Biotite. — Micaceous minerals. $n >$ oil of cloves, $<$ bromoform. Cleavage flakes practically isotropic. Negative biaxial interference figure with small axial angle (often practically uniaxial).

Digitized by Google

Borax. — (Recrystallized, Plate I.) Monoclinic crystals with (1) low interference colors and oblique extinction, (2) bright interference colors and parallel or symmetrical extinction.

Brochantite, IV. — Green. n(‖ elongation) > methylene iodide, < sulfur in methylene iodide; n(⊥ elongation) < methylene iodide < monobromnaphthalin. Parallel extinction. Elongation ‖ c'. Soluble in HNO_3 and with calcite gives microchemical gypsum. Solution deposits copper on knife-blade.

Brucite, V., and Micaceous Minerals. — n > oil of cloves, < bromoform. Cleavage flake is uniaxial positive (sometimes slightly biaxial). Lines at angles of 60° and 120°. Fibrous brucite. (V.) has low interference colors. Parallel extinction. Elongation ‖ a'. Soluble in HCl. Add NH_4OH. and S.Ph., obtain white precipitate which with high-power objective is seen to be microchemical struvite. (Fig. 2.)

Calamine, IV. and VI. — n > monoiodobenzene, < monobromnaphthalin. Bright interference colors. Parallel extinction. Elongation ‖ c'. Sinks in methylene iodide. Soluble in HCl with gelatinization.

Calcite, III. — Rhombs with striations parallel to long diagonal, n (short diagonal) > oil of cloves, < bromoform; n (long diagonal = monobromnaphthalin. High-order interference colors. Symmetrical extinction. Effervesces rapidly with HCl. H_2SO_4 gives microchemical gypsum. (Fig. 3.) Floats on bromoform. The striations parallel to long diagonal of rhomb which represent twinning parallel to $(01\bar{1}2)$ are produced in crushing and serve to distinguish calcite from all other rhombohedral carbonates.

Carnallite. — (Recrystallized, Plate I.) At first isotropic squares (KCl) crystallize out, then anisotropic squares (symmetrical extinction) or rectangles (oblique extinction) ($KCl \cdot MgCl_2$) with n > balsam separate. These are twinned crystals one half of which gets dark and light while the other half has uniform illumination. Later the whole is connected by streaked aggregates (low-order colors) of $MgCl_2$ (?).

Celestite. — The same as for barite.

Cerussite, IV.–VII. — Mostly irregular but some elongate ones. (‖ extinction elongation ‖ a) n > sulfur in methylene iodide. High interference colors. Effervesces with HNO_3, octahedral crystals of $Pb(NO_3)_2$ crystallize out. With HCl the mineral turns white.

Chabazite, II., VII. — Square-like rhombs and irregular. n <

Digitized by Google

benzol. Low-order interference colors. Rhombs have symmetrical extinction. Soluble in HCl leaving residue of lumps of jelly and cubes of NaCl.

Chalcanthite. — (Recrystallized, Plate I.) Pale blue crystals. Bright interference colors. Oblique extinction (10 to 15°). Elongation $\| c'$. With calcite and HCl gives SO_4 test. Solution coats knife-blade with copper.

Chondrodite, VII. — Irregular. Colorless and yellow. The latter are pleochroic (light to darker yellow) but not always marked. $n >$ monobromnaphthalin, $n <$ methylene iodide. Bright interference colors. Gelatinizes with HCl. On addition of NH_4OH precipitates with S.Ph.(Mg.).

Chrysoberyl, VII.— $n >$ methylene iodide; $n <$ sulfur in methylene iodide. Low-order interference colors. Insoluble.

Chrysocolla, VII. — Colorless to pale green or blue. $n >$ oil of cloves, $<$ bromoform. Aggregate polarization — isotropic in part, low order-colors. Gelatinizes with HCl. Solution deposits copper on knife-blade.

Chrysolite. — See olivine.

Cinnabar, VII.— Red, translucent. $n >$ sulfur in methylene iodide. Interference colors masked by red color.

Clinochlore. — Micaceous minerals. $n >$ oil of cloves, $<$ bromoform. Biaxial interference figure, axial angle variable, usually small and positive.

Colemanite, VI. — Flat plates, but no constant shape. n ($\|$ elongation) $>$ bromoform, $<$ monoiodobenzene. n($\perp$ elongation) $>$ oil of cloves, $<$ bromoform. Bright interference colors. Some $\|$ extinction, elongation $\| c'$; others, extinction 20 to 25°. Soluble in HCl. On standing crystals of H_3BO_3 (see sassolite, Plate I.) separate out. H_2SO_4 gives microchemical gypsum.

Copiapite, VI., VII. — Pleochroic (pale to deeper yellow). $n >$ oil of cloves, $<$ bromoform. Bright interference colors. partly soluble in water.

Corundum, VII. — $n >$ methylene iodide, $<$ sulfur in methylene iodide. Low interference colors. Sinks in methylene iodide. Insoluble.

Cryolite, II., VII. — Rough rectangular cleavage. $n <$ benzol. Relief very high in balsam, but low in water. Low interference colors. Oblique extinction, polysynthetic twinning. Soluble in HCl.

Digitized by Google

Cuprite, VII. — Irregular, translucent red, $n >$ sulfur in methylene iodide. Isotropic. Coated white with HCl, then dark liquid, then aggregates of needle crystals.

Cyanite, IV. and V. — Transverse cleavages at almost right angles. $n >$ monobromnaphthalin; $n <$ methylene iodide. Rather low interference colors. Oblique extinction, about 30°. Elongation $\parallel c'$. Cleavage plate gives biaxial negative interference figure with large axial angle.

Datolite, VII. — Irregular, very angular, conchoidal fracture. $n >$ moniodobenzene; $n <$ methylene iodide. Bright interference colors. Gelatinizes with HCl. H_2SO_4 gives microchemical gypsum.

Diaspore, IV. and VI. — n($\parallel$ elongation) $>$ monobromnaphthalin, $n <$ methylene iodide; n($\perp$ elongation) $>$ methylene iodide, $n <$ sulfur in methylene iodide. Bright interference colors. Parallel extinction. Elongation $\parallel a'$. Sinks in methylene iodide.

Dolomite, III. — No striations as in calcite. n(short diagonal) $>$ oil of cloves, $<$ bromoform; n(long diagonal) $>$ monobromnaphthalin, $<$ methylene iodide. High-order colors, symmetrical extinction. Slow effervescence in HCl H_2SO_4 gives microchemical gypsum. NH_4OH and S.Ph. give microchemical struvite at first, then later larger thin flat crystals (calcium phosphate?).

Enstatite, IV. — Colorless, may have inclusions. $n >$ monobromnaphthalin; $n <$ methylene iodide. Low interference colors. Parallel extinction. Elongation $\parallel c'$.

Epidote, VII. — Mostly irregular. Yellowish-green, some fragments pleochroic. $n >$ methylene iodide; $n <$ sulfur in methylene iodide. Bright interference colors. Cleavage fragments ($\parallel$ 001) give axial bar. Sinks in methylene iodide.

Erythrite, IV. — Strongly pleochroic, pink to deep red (deepest color is in diagonal position). $n >$ monobromnaphthalin; $n <$ methylene iodide. Bright interference colors. Oblique extinction (about 32°). Elongation $\parallel c$. Soluble in HCl.

Epsomite. — (Recrystallized, Plate I.) Aggregates with rhombic ends. Low-order colors. Parallel extinction. SO_4 test and Mg test.

Fluorite, I. — Triangular fragments. $n <$ benzol. Isotropic. Soluble in HCl with H_2SO_4 microchemical gypsum.

Garnet, VII. — Irregular conchoidal fracture. Colorless to pink. $n >$ soluble in methylene iodide. Isotropic.

Digitized by Google

Garnierite, VII. — Irregular. Greenish. $n >$ oil of cloves; $n <$ bromoform. Aggregate polarization, mostly low colors. Partially soluble in HCl. With NH_4OH and S.Ph. microchemical struvite.

Gibbsite, IV. — Aggregate structure. Low-order colors. Mostly parallel extinction. $n >$ oil of cloves; $n <$ bromoform with elongation $\parallel a'$.

Glauberite. — Partly soluble in water. First minute needle crystals of gypsum, then crystals of Na_2SO_4 (see thenardite).

Gœthite, IV. — Yellow-brown or reddish-brown, translucent. Only transparent in very thin plates. $n >$ sulfur in methylene iodide. Parallel extinction. Elongation $\parallel c'$ (very difficult to get).

Goslarite.—(Recrystallized, Plate I.) Like epsomite but microchemical test for zinc (tetrahedral crystals with Na_2CO_3).

Gypsum, IV., V., VI. — $n >$ benzol, $<$ oil of cloves. Bright interference colors. Extinction angles either 0°, 13½° or 37½°. Elongation usually $\parallel c'$. Soluble in HCl, microchemical gypsum redeposited *without* addition of H_2SO_4.

Halite.—(Recrystallized, Plate I.) Cubes often hopper-shaped. $n >$ oil of cloves, $<$ bromoform. Isotropic. With HNO_3 gives $NaNO_3$, rhombs with high-order colors and symmetrical extinction.

Heulandite, IV., VI. — $n <$ benzol. IV., Bright interference colors. $\parallel$ Extinction, elongation $\parallel a'$. VI., Low interference colors. Extinction 25° to 30°. Biaxial interference figure. Soluble in HCl. H_2SO_4 gives microchemical gypsum.

Hypersthene, IV. — Inclusions frequent. Pleochroic, pink to greenish. $n >$ monobromnaphthalin; $n <$ methylene iodide. Bright interference colors. Parallel extinction, elongation $\parallel c'$.

Kainite. — (Recrystallized, Plate I.) First crystals of potassium magnesium sulfate with oblique extinction, then later isotropic squares of KCl, and finally these are covered with confused feathery aggregates ($MgCl_2$ and $MgSO_4$?).

Kalinite. — (Recrystallized, Plate I.) Octahedral crystals and crystal aggregates at 90°. Isotropic. With calcite and HCl gives microchemical gypsum.

Labradorite, VI. — Inclusions frequent. $n >$ oil of cloves; $n <$ bromoform. Low-order colors. Extinction on 001, 5½°; on 010, — 20°. Polysynthetic twinning frequent.

Leucite, VII. — $n >$ benzol, $<$ oil of cloves. Isotropic in part, in part anisotropic. Low-order interference colors. Twinning lamellæ. Soluble in HCl.

Digitized by Google

Lepidolite. — Micaceous minerals. Like muscovite.

Linarite, IV. — Blue color, not pleochroic. $n >$ sulfur in methylene iodide. Bright interference colors. Parallel extinction, elongation $\| c'$. Soluble in HNO_3 leaving white residue. Solution coats knife-blade with copper, and on evaporation leaves octahedral crystals of $Pb(NO_3)_2$.

Magnesite, III. — n(short diagonal) > monoiodobenzene, < monobromnaphthalin; n(long diagonal) > monobromnaphthalin, < methylene iodide. High interference colors. Symmetrical extinction.

Malachite, IV. — Green color. n(|| elongation) > monobromnaphthalin, < methylene iodide; n(⊥ elongation) > methylene iodide, < sulfur in methylene iodide. Bright interference colors (only small fragments show). Oblique extinction (about 23°). Arrowhead twins like gypsum very common. Effervesces in HC. giving spindle-shaped fragments. Knife-blade coated with copperl

Margarite. — Micaceous minerals. $n >$ bromoform, < moniodobenzene.

Melanterite. — (Recrystallized, Plate I.) Like epsomite but no Mg test.

Microcline, VI. — $n >$ benzol, < oil of cloves. Low-order colors, Small extinction angles. Crossed twinning.

Mirabilite. — (Recrystallized, Plate I.) Long, orthorhombic crystals. Parallel extinction.

Monazite, VI. — $n >$ soluble in methylene iodide. Faint yellow color. Interference colors rather high, usually third to fifth order.

Muscovite. — Micaceous minerals. $n >$ oil of cloves, < bromoform. Biaxial negative. Large axial angle.

Natrolite, IV., V. — $n <$ benzol. Bright interference colors parallel extinction. Elongation $\| c'$. Gelatinizes with HCl, isotropic cubes deposited (NaCl).

Nephelite, VII., IV. — $n <$ oil of cloves, < bromoform. Low interference colors. IV., Parallel extinction. Elongation $\| a'$. Gelatinizes with HCl, isotropic cubes deposited (NaCl).

Niter. — (Recrystallized, Plate I.) Prismatic crystals and aggregates. Parallel extinction. Elongation $\| a'$.

Oligoclase, VI. — $n >$ oil of cloves; $n <$ bromoform. Low-order colors. Extinction on 001, 2°; on 010, 8°. Polysynthetic twinning.

Olivine, VII. — $n >$ monobromnaphthalin; $n <$ methylene iodide.

Digitized by Google

Bright interference colors. Soluble in HCl. With NH_4OH and S.Ph. Mg test.

Opal, VII. — High relief. $n <$ benzol. Isotropic in whole or part. Insoluble.

Orpiment. — Micaceous minerals. $n >$ sulfur in methylene iodide. Parallel extinction. No interference figure.

Orthoclase, VI. — $n >$ benzol, $<$ oil of cloves. Low interference colors. Extinction on 001, 0°; on 010, 5°.

Pectolite, V. — n(‖ elongation) = bromoform; n(‖ elongation) > monoiodobenzene, < monobromnaphthalin. Bright interference colors. ‖ extinction, elongation ‖ c'. Gelatinizes with HCl, depositing isotropic cubes (NaCl). H_2SO_4 gives microchemical gypsum.

Phlogopite. — Micaceous minerals. $n >$ bromoform, < monoiodobenzene. Often with regularly arranged inclusions. Biaxial interference figure, negative, small axial angle.

Prehnite, IV., VII. — $n >$ monoiodobenzene, < monobromnaphthalin bright interference colors. Parallel extinction, elongation ‖ a'. Soluble in HCl. H_2SO_4 gives microchemical gypsum.

Prochlorite, VII. — Green. $n >$ monobromnaphthalin, < methylene iodide. Aggregate structure. Very low interference colors.

Proustite, VII. — Red translucent. Interference colors masked.
Pyrargyrite. $n >$ sulfur in methylene iodide.

Pyromorphite, VII. — Colorless to green. $n >$ sulfur in methylene iodide. Low interference colors. Whitens with HCl. Soluble in HNO_3 depositing $Pb(NO_3)_2$ crystals.

Pyroxene, IV. — Colorless to green. Not pleochroic. $n >$ monoiodobenzene, < monobromnaphthalin. Bright interference colors. Oblique extinction. Large angle 30 to 45°. Elongation ‖ c' Diallage has parallel extinction in part.

Pyrophyllite, IV. — n(‖ elongation) > bromoform, < moniodobenzene; n(⊥ elongation) > oil of cloves, < bromoform. Low-order interference colors. Parallel extinction. Elongation ‖ c'.

Quartz, VII. — Conchoidal fracture. $n >$ oil of cloves, < bromoform. Bright interference colors (high first and low second order). Insoluble.

Realgar, VII. — Pleochroic (yellow to orange). $n >$ sulfur in methylene iodide. Interference colors masked.

Rhodochrosite, III. — n(short diagonal) > monobromnaphthalin, < methylene iodide; n(long diagonal) > sulfur in methylene iodide.

Digitized by Google

High-order interference colors. Symmetrical extinction. Slightly soluble in cold HCl (few bubbles).

Rhodonite, IV. — $n >$ monobromnaphthalin, $<$ methylene iodide. Bright interference colors. Oblique extinction 20° to 25°. Elongation $\parallel c'$.

Rutile, VII. — Yellow. $n >$ sulfur in methylene iodide. High-order interference colors.

Sal-ammoniac. — (Recrystallized, Plate I.) Skeleton crystals at 60° (or 90°). Isotropic. $n >$ monoiodobenzene, $<$ monobromnaphthalin.

Sassolite. — (Recrystallized, Plate I.) (*a*) Branching aggregates and tree-like threads, bright interference colors. (*b*) Six-sided plates with low interference colors.

Scheelite, VII. — Colorless. $n >$ sulfur in methylene iodide. Bright interference colors. With HCl after standing gives yellow coloration (WO_3).

Sepiolite, VII. — $n <$ Benzol. Aggregate structure. Low-order interference colors.

Serpentine, VII., V. — $n >$ oil of cloves, $<$ bromoform. Aggregate structure. Low-order colors. Chrysotile has parallel extinction, elongation $\parallel c'$.

Siderite, III. — (Iron stains common.) n(short diagonal) $>$ methylene iodide, $<$ sulfur in methylene iodide; n(long diagonal) $>$ sulfur in methylene iodide. High-order interference colors. Symmetrical extinction. Does not effervesce in cold dilute HCl.

Sillimanite, IV. — $n(\parallel$ elongation$) >$ monobromnaphthalin, $<$ methylene iodide; $n(\perp$ elongation$) >$ monoiodobenzene, $<$ monobromnaphthalin. Bright interference colors. $\parallel$ extinction, elongation $\parallel c'$.

Smithsonite, III. — n(short diagonal) $>$ methylene iodide, $<$ sulfur in methylene iodide; n(long diagonal) $>$ sulfur in methylene iodide. High-order interference colors. Symmetrical extinction. Effervesces with HCl.

Sphalerite, I. and VII. — Colorless to yellow, red or brown. $n >$ sulfur in methylene iodide. Isotropic in part, anisotropic in part. H_2S odor with HCl.

Spinel, VII. — Colorless. $n >$ monobromnaphthalin, $<$ methylene iodide. Isotropic.

Spodumene, IV. — $n >$ monobromnaphthalin, $<$ methylene iodide. Rather low interference colors. Oblique extinction (20 to 25°). Elongation $\parallel c'$.

Digitized by Google

Soda Niter. — (Recrystallized, Plate I.) Rhombs with high-order interference colors and symmetrical extinction.

Staurolite, VII. — Pleochroic, light to deeper yellow, $n >$ monobromnaphthalin, $<$ methylene iodide. Mostly first-order interference colors. Inclusions frequent. Remains suspended in methylene iodide.

Stilbite, IV. — $n <$ oil of cloves. Bright interference colors. Parallel extinction. Elongation $\parallel a'$. Soluble in HCl. H_2SO_4 gives microchemical gypsum.

Strontianite, IV. — n(|| elongation) $>$ monobromnaphthalin, $<$ methylene iodide; n($\perp$ elongation) $>$ benzol, $<$ oil of cloves. High-order interference colors. Parallel extinction. Elongation $\parallel a'$. Effervesces with HCl, slender crystals of $SrCl_2$ crystallizing out.

Sulfur, VII. — $n >$ sulfur in methylene iodide. High-order interference colors. Soluble in methylene iodide.

Sylvite. — (Recrystallized, Plate I.) Squares and crystal aggregates. $n >$ benzol. Add HNO_3, obtain KNO_3 (long crystals, bright colors, parallel extinction).

Talc. — Micaceous minerals. $n >$ oil of cloves, $<$ bromoform. Biaxial negative, small axial angle.

Thenardite. — (Recrystallized, Plate I.) Like mirabilite.

Titanite, VI., VII. — Colorless to yellowish or brownish, slightly pleochroic, $n >$ sulfur in methylene iodide. High-order interference colors.

Topaz, VI. and VII. — $n >$ bromoform, $<$ monoiodobenzene. Low-order interference colors. Insoluble.

Tourmaline, VII. — Colorless or black variety, pleochroic (smoke colored to black). $n >$ monoiodobenzene, $<$ monobromnaphthalin. Bright order colors.

Trona. — (Recrystallized, Plate I.) Small radial aggregates or dendritic groups with spherulitic structure. Effervesces in HCl.

Turquois, VII. — Bluish or greenish. $n >$ bromoform, $n <$ monoiodobenzene. Aggregate polarization. Low-order colors. Slightly soluble in HCl, but no copper deposited on knife-blade. PO_4 test on addition of HNO_3 and $(NH_4)_2MoO_4$.

Ulexite, V. — Minute fibers. $n >$ benzol, $<$ oil of cloves. Low interference colors. Parallel extinction. Elongation $\parallel a$. Soluble in HCl. H_3BO_3 separates out (see Sassolite, Plate I.).

Vanadinite, VII. — Yellow or orange color. $n >$ sulfur in meth-

Digitized by Google

ylene iodide. Bright interference colors. Soluble in HNO_3. $Pb(NO_3)_2$ crystallizes out.

Vesuvianite, VII. — $n >$ monobromnaphthalin, $<$ methylene iodide. Low-order interference colors.

Vivianite, IV. — Many pleochroic (green to blue, or colorless to blue). n(|| elongation) $>$ monoiodobenzene, $<$ monobromnaphthalin. n($\perp$ elongation) $>$ bromoform, $<$ monoiodobenzene. Parallel extinction. Elongation || c' and oblique extinction. (28 to 30°.) Elongation || a'. Soluble in HNO_3. $(NH_4)_2MoO_4$ gives yellow precipitate.

Wavellite, IV. and V. — n(|| elongation) $>$ oil of cloves, $<$ bromoform; n($\perp$ elongation) $>$ benzol, $<$ oil of cloves. Bright interference colors. Parallel extinction. Elongation || c'. Soluble in HCl. Add HNO_3 and $NH_4 Mo{\cdot}O_4$ — yellow precipitate.

Wernerite, IV. — $n >$ oil of cloves, $<$ bromoform. Bright interference colors. || extinction. Elongation || a'. Soluble in HCl, with H_2SO_4, microchemical gypsum.

Willemite, VII. — $n >$ monobromnaphthalin, $<$ methylene iodide. Bright interference colors. Gelatinizes with HCl.

Witherite, IV. and VI. — n(|| elongation) $>$ monobromnaphthalin, $<$ methylene iodide; n($\perp$ elongation) $>$ oil of cloves, $<$ bromoform. High-order colors. Parallel extinction. Elongation || a'. Effervesces with HCl. Crystals of $BaCl_2$ (Fig. 1) form.

Wollastonite, IV. and V. — $n >$ monoiodobenzene, $<$ monobromnaphthalin. Bright interference colors. || extinction. Elongation || c'. Gelatinizes with HCl (may also effervesce) microchemical gypsum with H_2SO_4.

Wulfenite, VII. — Yellow. $n >$ methylene iodide, $<$ sulfur in methylene iodide. Rather high interference colors. Turns white with HCl, needle crystals, $PbCl_2$, forming.

Zincite, IV., VII. — Yellow or orange. Not pleochroic. $n >$ sulfur in methylene iodide. IV., Parallel extinction. Interference colors masked.

Zircon, VII. — $n >$ sulfur in methylene iodide. High-order interference colors.

Digitized by Google

Minerals Arranged according to Indices of Refraction with Respect to Certain Liquids.

(‖, long direction parallel to vibration plane of lower nicol; ⊥, perpendicular to same.)

Analcite
Chabazite
Cryolite
Fluorite
Heulandite
Natrolite
Opal
Sepiolite
Stilbite

Benzol

Albite
Gypsum
Leucite
Microcline
Orthoclase
Strontianite ⊥
Ulexite
Wavellite ⊥

Oil of cloves

Alunite
Amblygonite
Anhydrite
Apophyllite
Beryl
Biotite
Brucite
Calcite (short diag. ‖)
Chrysocolla
Clinochlore
Colemanite
Copiapite
Dolomite (short diag. ‖)
Garnierite
Gibbsite
Labradorite
Lepidolite
Muscovite
Nephelite
Oligoclase
Pyrophyllite ⊥
Quartz
Serpentine
Wavellite ‖
Wernerite
Witherite ⊥

Bromoform

Calamine
Colemanite ‖
Margarite
Pectolite ‖
Phlogopite
Topaz
Turquois
Vivianite ⊥

Monoiodobenzene

Andalusite
Apatite
Aragonite ‖
Barite
Celestite
Datolite
Magnesite (short diag. ‖)
Pectolite ⊥
Prehnite
Pyrophyllite ‖
Pyroxene
Sillimanite ⊥
Tourmaline
Vivianite ‖
Wollastonite

α-Monobromnaphthalin

Amphibole
Aragonite ⊥
Brochantite ⊥
Calcite (long diag. ‖)
Chondrodite
Cyanite
Diaspore ‖
Dolomite (long diag. ‖)
Enstatite
Erythrite
Hypersthene
Hornblende
Magnesite (long diag. ‖)
Malachite ‖
Olivine
Prochlorite
Rhodochrosite (short diag. ‖)
Rhodonite
Sillimanite ‖
Spinel
Spodumene
Staurolite
Strontianite ‖
Vesuvianite
Willemite
Witherite ‖

Methylene iodide

Ægirite ‖
Atacamite ‖
Brochantite ‖
Chrysoberyl
Corundum
Diaspore ⊥
Epidote
Malachite ⊥
Siderite (short diag. ‖)
Smithsonite (short diag. ‖)
Wulfenite

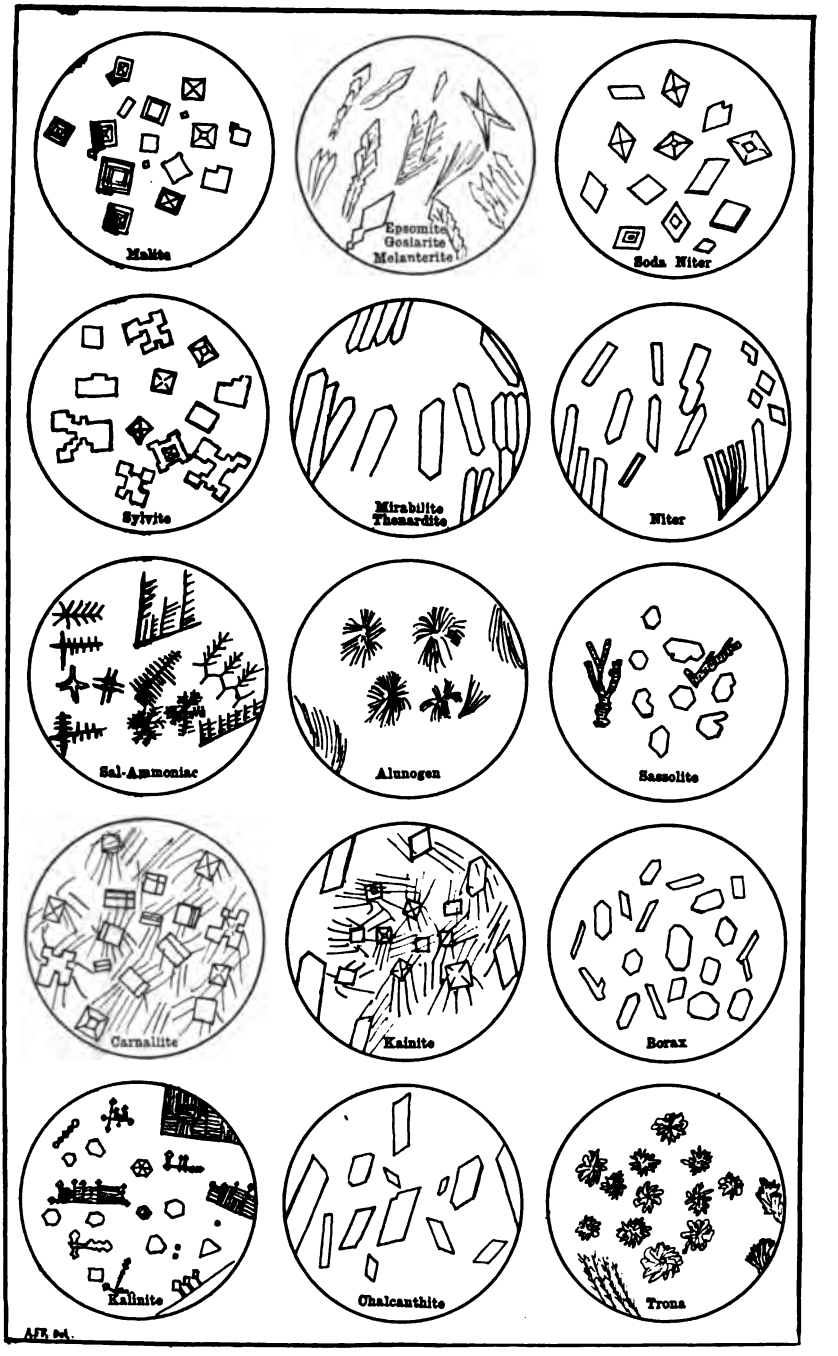
Sulfur in methylene iodide

Ægirite ⊥
Anglesite
Atacamite ⊥
Azurite
Cerussite
Cinnabar
Cuprite
Garnet
Goethite
Linarite
Monazite
Orpiment
Proustite
Pyrargyrite
Pyromorphite
Realgar
Rhodochrosite (long diag. ‖)
Rutile
Scheelite
Siderite (long diag. ‖)
Smithsonite (long diag. ‖)
Sphalerite
Sulfur
Titanite
Vanadinite
Zincite
Zircon

Digitized by Google

Digitized by Google

Digitized by Google



Soluble Minerals Recrystallized.

Digitized by Google

ALUMNI AND UNIVERSITY NEWS.

CIVIL ENGINEERING.

NOTES ON DEPARTMENTAL WORK.

During the current year Mr. Chas. E. Morrison, C.E., A.M., has taken the position of assistant in civil engineering, but with that exception there has been no change in the personnel of the instruction force of the department.

A material development in the course of instruction in C.E. 5 has been made in the endeaver to give it if possible greater directness and to make it practicable for students to attain required efficiency without the necessity of an examination either at the mid-year or at the period of the final examinations. This has been done by requiring evidence of greater facility in the application of knowledge gained, the evidence being secured by holding fortnightly examinations. Those students who at the end of the session have shown attainment of excellence in work represented by a grade of at least eight out of a possible ten are excused from the examination at the end of the session. The results have been eminently satisfactory and it is believed that an extension of this feature of educational work may advantageously be made. This does not in any way trench upon the practical problem and design work to which the afternoon hours are devoted but adds interest and efficiency to it.

In sanitary science, the third-year students, as has been the custom heretofore, are required to supplement their theoretical knowledge by visits to representative plants in actual operation.

These trips are usually taken at the Christmas holidays when the men have the time to make a more careful and thorough investigation of the methods and practice as adopted at the places visited, and embrace the New England territory together with the more local districts. As a proof of work done a paper is required of each student setting forth the conditions and characteristics of the plant which it has been his business to investigate. The papers are read in the presence of the class and have the advantage of not only fixing in the individual's mind the features of the plant of which he has been the particular investigator, but also of presenting to the other students those features from the under-gradua'e standpoint. The subjects include water filtration, sewage disposal, sewage farming, and in fact all branches of sanitary science. Besides, the students of this subject during the past year have had the opportunity and privilege of listening to lectures by Messrs. Whipple and Hazen. Mr. Whipple gave a talk on "Color Determination of Water," while Mr. Hazen lectured on "Mechanical Filters." Both lectures were well attended and deeply appreciated.

The subject of hydraulics has been materially strengthened by devoting one afternoon each week to problem work in the draughting room

Digitized by Google

under the direct supervision of the instructor. In this way as many as eighty problems have been solved during a term and the application of the theory demonstrated.

Due to the fact that the mining department is now occupying its own building, the civil engineering department has taken over the rooms made vacant, for offices, library and museum. The offices as occupied previously by the Professor and Adjunct Professor of Mining are now occupied by the Adjunct Professor and Instructor of Civil Engineering. It is the intention, as soon as the appropriation can be secured, to make the room formerly used by the mining department as library, satisfy similar needs for the civil engineering department, and the old mining museum will perform a similar function for civil engineering. At present the museum is sadly in need of equipment but it is hoped through the generosity of our graduates this may be overcome in the not far distant future.

CHARLES L. WOODHOUSE.

Last spring the Philippine Islands was the scene of a most unfortunate accident in which Columbia University lost an alumnus of great promise and the army an exceedingly capable and efficient officer. On the afternoon of May 4, 1905, First Lieutenant Charles L. Woodhouse, Fourth Infantry and Columbia '97, was sailing on Laguna de Bay with a small party from the post at Los Banos, when an accident threw one of the party, another officer, into the water. Not realizing the danger he, though a powerful swimmer, soon became entangled in the long ribbonlike grass. Lieutenant Woodhouse leapt and swam to his rescue only to meet a similar fate and both succumbed. Lieutenant Woodhouse attended the class of 1897 Columbia School of Mines and entered the United States Army through the ranks of the artillery, receiving his commission as Second Lieutenant June 25, 1902. He saw service in Cuba, Alaska, China and the Philippines. As a Quartermaster he built part of the Military road from Iligan to Lake Lanao, in Mindanao, and took part in several campaigns against the Moros. Transferred to the Fourth Infantry, December 10, 1903, he joined that regiment at Los Banos, Laguna Province, where he served until his death. In Lieutenant Woodhouse Columbia lost an alumnus who did credit to her highest ideals, and the army an officer of the highest type. He was a man of strength and solidity, cool in judgment, conscientious in the performance of his duties, very efficient and ambitious in his chosen profession. A gentleman in every sense of the word, he won the respect and friendship of officers and men.

"Greater love hath no man than this, that a man lay down his life for his friend."

Digitized by Google

Francis Gordon Brown, who died on December 21, 1905, at his residence in Flushing, Long Island, was a member of the first class which graduated from the School of Mines. He received the degree of Engineer of Mines in 1867. After a year's work in mining in the West he returned to New York and entered his father's business. Mr. Brown was a life member of the Association of the Alumni of Columbia College.

Digitized by Google

BOOK REVIEWS.

The Cyanide Industry. Theoretically and Practically Considered. By R. ROBINE and M. LENGLER. Translated by J. A. LECLERC, Ph.D. 8vo, 408 pages. New York, John Wiley & Sons, 1906.

The book is a useful collection of facts relating to simple and complex cyanides; it is divided into four parts as follows: Part I., Chemistry of Cyanogen and its Derivatives, 69 pages; Part II., Present Condition of the Cyanide Industry, 11 pages; Part III., Methods of Manufacturing Cyanide Compounds, 212 pages; Part IV., The Use of Cyanogen Compounds, 82 pages, including a digest of United States patents, by C. E. Munroe, Ph.D.

The main portion of the work consists of descriptions of industrial processes, both successful and unsuccessful, taken up chronologically, for cyanides, ferrocyanides and sulphocyanides. This will prove of use to those interested in the development of the cyanide industry.

The portion devoted to the analysis of cyanides, etc., is open to criticism; it is too brief to be of much practical use, and avoids rather than attempts to explain the well-known difficulties. While it is perhaps unessential, it might be noted that the graphic formula given for hydroferricyanic acid, that of Friedel, is not usually employed at present.

A description of the cyanide process for the extraction of gold from ores is included in Part IV.

The book is systematically arranged, contains a good index, and is well printed and bound.

E. H. M.

Notes on Electrochemistry. By F. G. WIECHMAN, Ph.D. New York, McGraw Publishing Co., 1906. Price $2.00 net.

This little volume of 141 pages gives briefly the principles which underlie the science of electrochemistry, and also its practical applications.

The book opens with a description of the general principles of science, matter and energy, and the theories of electricity. The electron theory of J. J. Thomson is given place and also the bearing of the phenomena of radio-activity. The general phenomena of electricity and a discussion of Ohm's law completes this portion of the book.

The subject of electrochemistry is taken up from an historical standpoint, Faraday's law, and the calculation of the dissociation voltage from thermic data being discussed with some detail. It would have been well however to point out a little more fully the limitations in the use of this method for the calculation of voltage.

The theory of electrolytic dissociation is given place and the practical applications are mentioned in connection with the modern views of electrochemistry. Indeed throughout the book there is rather a happy blending of theory and practice which is of great advantage.

Digitized by Google

The rest of the volume deals with the subject of applied electrochemistry. This is given in short descriptions of the more important processes in use to-day, both strictly electrochemical and also thermic processes in which electricity provides the heat necessary to bring about a given reaction.

The temperature for the formation of carborundum and siloxicon as given on page 131 is much too high in view of recent investigations of this subject.

Each chapter is headed with a short bibliography of books on the subject treated of, indeed the book as a whole will be found alike useful to the student desiring an introduction to the study of electrochemistry, and to the general reader who wishes information in this subject in an exceedingly handy form.

S. A. T.

Experimental Electrochemistry. By N. MONROE HOPKINS, Ph.D. New York, D. Van Nostrand Company, 1905.

This volume aims at the study of electrochemistry from the experimental standpoint.

Little if any knowledge of chemistry or electricity appears to be presupposed on the part of the reader, and yet the subjects dealt with are not easy of comprehension without such knowledge.

The book opens with an historical sketch of the subject which takes the reader from the researches of Sir Humphry Davy to those of Arrhenius at one jump; this of course gives no information as to what was accomplished in the mean time. The theory of electrolytic dissociation is then taken up, and a number of experiments described supporting it. Somewhat elaborate experiments are given in connection with the determination of electrolytic conduction, and occasionally a list of definitions are introduced. In one place such a list includes specific inductive capacity, molecular conductivity and "bumping" side by side. In Chapter VI. Faraday's law is illustrated by experiment after the manner of Lupke, but the following experimental descriptions have little if anything to do with it.

Electrolytic separation of metals has a brief description, much stress being laid on the "attractive device known as the rotating anode."

The rest of the book deals with the preparation of certain compounds by electrolysis, and this includes some experiments with the electric furnace, as well as the electrolyses of fused salts. The production of aluminum is merely described by giving the patent literature on the subject.

The book concludes with a rather complete bibliography.

It is too much to expect of any book that it will deal with all that has been done in electrochemistry whether in theory or practice, and yet such has apparently been the endeavor of the author. It is not surprising that it falls short in this fulfillment.

The style in which the author writes is unworthy that of any scientific book.

The volume is attractively gotten up and is profusely illustrated.

S. A. T.

Digitized by Google

THE

SCHOOL OF MINES QUARTERLY.

VOL. XXVII. JULY, 1906. No. 4.

GEOLOGY OF PIOCHE, NEVADA, AND VICINITY.

FRED J. PACK.

TABLE OF CONTENTS.

Part III. — Economic Geology. Page.

History of the Ely Mining District 365
The Ore Bodies 369
Fissure Veins 369
Contact Deposits 372
Bedded Deposits 373
Age of the Ore Bodies 376
Fissure Veins 376
Bedded Veins 377
Contact Deposits 378
Relation of the Ore Bodies to the Igneous Intrusions 378
Processes of Mining 382
Processes of Reduction 383
Production of the Ely Mining District 385

PART III. ECONOMIC GEOLOGY.

HISTORY OF THE ELY MINING DISTRICT.

Very little is know of the early history of Pioche. It appears, however, that ore was first discovered by some of General P. E. Connor's soldiers in 1862. Two years later some prospectors from Salt Lake City formed a mining district and staked off some claims, among which were the Burke and Panaca of later years. Very little work was done and the district was practically abandoned.

Digitized by Google

The Mormon village of Panaca is situated eleven miles to the south; it is said that on several occasions citizens of that community raised considerable excitement over the supposed ore bodies at Pioche. Practically nothing was done, however, until the summer of 1869 when John Ely and some other San Francisco mining men decided to prospect the region. A new district was formed, and new laws were adopted. The Burke mining claim was the first to be located. A shaft sunk upon it revealed good ore from grass roots. Excitement ran wild. Scores of claims were located in the immediate vicinity, many of which later became good producers.

Among the many misguided efforts in the early history of the camp was the building of a smelter in the winter of 1869–70, before the ores had been tested as to the proper method of treatment. The smelter proved a failure, for the reason that there was not sufficient lead in the ores to carry down the silver and gold values.

It was left to Alix Janin of White Pine to propose a treatment for the ores. He demonstrated that they would yield readily to amalgamation when salt and bluestone were added. Mills were, therefore, constructed at several points in the region as close to the mines as the water supply would permit. Mr. W. H. Raymond, an owner of one of the mills, and Mr. Ely soon became partners and incorporated the Raymond and Ely Mining Company. The company owned the Burke, Creole and Vermillion mines, which were practically the only ones operated by it in 1869–70.

The Meadow Valley Mining Company was also incorporated in the fall of 1869, and immediately took the lead in the district's production. This company owned nearly 2,500 feet along the outcrop of the great Pioche vein. Prospecting was energetically pushed, and large ore bodies were soon revealed.

The Raymond and Ely and Meadow Valley mining companies soon established themselves as the principal producers of the district. During the year 1871 the latter company still retained its position in the lead with a production of $1,753,708, against $1,361,628 of the former.

The Raymond and Ely Company was constantly acquiring more mining property, among which was the Panaca claim situated at the west of the Meadow Valley group. In the spring of 1871 Mr.

Digitized by Google

Lightner, superintendent of the company, sunk a shaft on this property through barren shale for a distance of 100 feet, and then very luckily struck the great "bonanza" of the district.

The year 1872 opened propitiously for both companies, but subsequent development proved that the expected output of the Meadow Valley Company's mines would not be realized. It became quite generally known that the ores in the lower levels were poorer than those nearer the surface, yet through persistent development they produced over a million dollars, and a dividend of half that amount was declared.

Through the enormous production of the Panaca mine the year 1872 became the banner year of the district. The output of this mine alone was nearly four million dollars.

Up to this time all the ores from the Raymond and Ely Company's mines had been freighted by team to the mill situated eleven miles to the south at Bullionville. During the year 1872 a railroad covering this distance was constructed and put into operation.

The production of the district for 1873 was much less than that of the previous year. This was brought about largely through litigation and decrease in ore values.

In the early part of 1874 the Lightner shaft was pushed to a depth of 1,214 feet where the water level was struck. In order to develop further it became necessary to install pumping machinery. An enormous ten-inch Cornish pump was put in place, and was practically ready to begin operations at the close of the year.

In July of the same year Meadow Valley shaft No. 3 reached a depth of 1,314 feet on the incline, at which point water was encountered. Prospecting was carried on thoroughly at water level but no large bodies of ore were discovered.

The mine operators were confident that a continuation of the great bonanzas would be found immediately below the permanent water, but the pumping machinery, ponderous as it was, proved entirely inadequate. The pumps continued in operation for four months without appreciably lowering the water. Exploration could be carried only 61 feet farther than before. After several unsuccessful attempts to master the water the ma-

Digitized by Google

chinery was stopped, and operations were confined to the upper workings.

The ore extracted in 1875 was taken largely from second-grade deposits that had been overlooked while the great bonanzas were in sight. The production was much less than that of any previous year.

There was no lack of prospecting above water. Literally thousands of feet of drifts were run on the varicus levels, but even this extensive prospecting uncovered no ore bodies of consequence.

The workings of the twelfth level of the Lightner shaft were pushed to the west for several hundred feet along the water line, but little or nothing of value was revealed. It is asserted that later this drift was carried 2,100 feet to the west of the shaft and there penetrated the so-called "black ledge." Upon this deposit a winze is reported to have been sunk some 300 feet revealing a large body of basic ore, which consisted of argentiferous lead and zinc sulphides.

The remaining history of the Raymond and Ely and Meadow Valley mining companies is brief. Both had money in the Bank of California, and when in 1876 it failed the last resource was gone. Operations immediately ceased. Others of the mining enterprises persisted in continuing the work, but when these two companies shut down the life of Pioche was gone.

For the last thirty years the mines have been practically idle, except for a season about 1890 when W. S. Godbe of Salt Lake City again started the wheels of the ponderous machinery at the Lightner shaft. The shaft was retimbered; the drift at water level was cleaned; and the water in the reported winze was raised. Again it was demonstrated that the pump was incapable of doing the required work, and operations were soon abandoned.

Mr. Godbe bought up many other mining properties, and for a time it appeared that the district would again become a heavy producer. A small smelter was built and proved quite efficient. Railroad connection was made with the mines at Jack Rabbit, sixteen miles distant. A second and larger smelter was soon constructed. Several mines along the Yuba Dyke were opened and profitably worked.

Digitized by Google

Mr. Godbe apparently believed in having his equipment of the very best design. Fortunes were spent in getting ready to work, instead of developing the mines on a large scale. Those who backed him financially grew tired of this policy, and when the fall came in the price of silver in 1893 all operations were suspen ed.

Just now the Nevada-Utah Mining Company is cleaning up around the buildings, preparatory to the reopening of some of the old workings.

THE ORE BODIES.

The ore deposits may be divided into three classes: the fissure veins, the contact deposits, and the bedded deposits. The fissure veins are by far the most important, especially from an economic standpoint. The great Raymond and Ely-Meadow Valley ore body belongs to this class, as do also the cross fissures. The contact deposits occur along the igneous dyke. The ore bodies found within this intrusion will also be considered with them. A typical example of the bedded deposit occurs at the Half Moon-Abe Lincoln property. There are also other bodies of this nature at the Mendha and the Point mines.

Each class will be discussed separately, but it may be previously stated that in general only a small part of the ore-bearing fissures are the immediate result of the original anticlinal movement. In other words, most of them were formed subsequent to that phenomenon unless, indeed, we may consider that it has not yet ceased. There is every reason to believe that the fissure veins at Pioche and the contact deposits were introduced at a comparatively recent date.

THE FISSURE VEINS.

The Raymond and Ely-Meadow Valley vein is situated on the north slope of the hill immediately south of Pioche. It strikes a few degrees north of east and dips to the south from 50 to 80 degrees, averaging very close to 70 degrees. The thickness varies from a mere seam to nine feet, the average being from two to four. It outcrops strongly in the quartzite, but when the shale and limestone formations on either side are reached it pitches down along the contact. It does not enter the limestone at the northeast, but a note in an official report states that a stringer was followed for two hundred feet into the limestone at the south-

Digitized by Google

west; no values, however, were found. The vein at both extremities continues quite strong to within a short distance from the contact and then suddenly goes to pieces.

In the majority of mining camps where limestones are involved in the section the ores have shown a decided preference for them, but at Pioche this rock has been avoided at nearly every point. This apparent exception is largely due to the fact that the ore carries but little lead which is the metal showing strong affinities for limestone. The rule is not so rigid in the case of silver ores without lead, if, indeed, it holds at all.

Immediately south of the town the vein emerges from the shale and strikes across the northern slopes of Treasure Hill in a direction 75 degrees east of north. It extends but a few hundred feet and then divides. Of the branches thus formed one continues in the course of the main vein; the other strikes nearly due eastward.

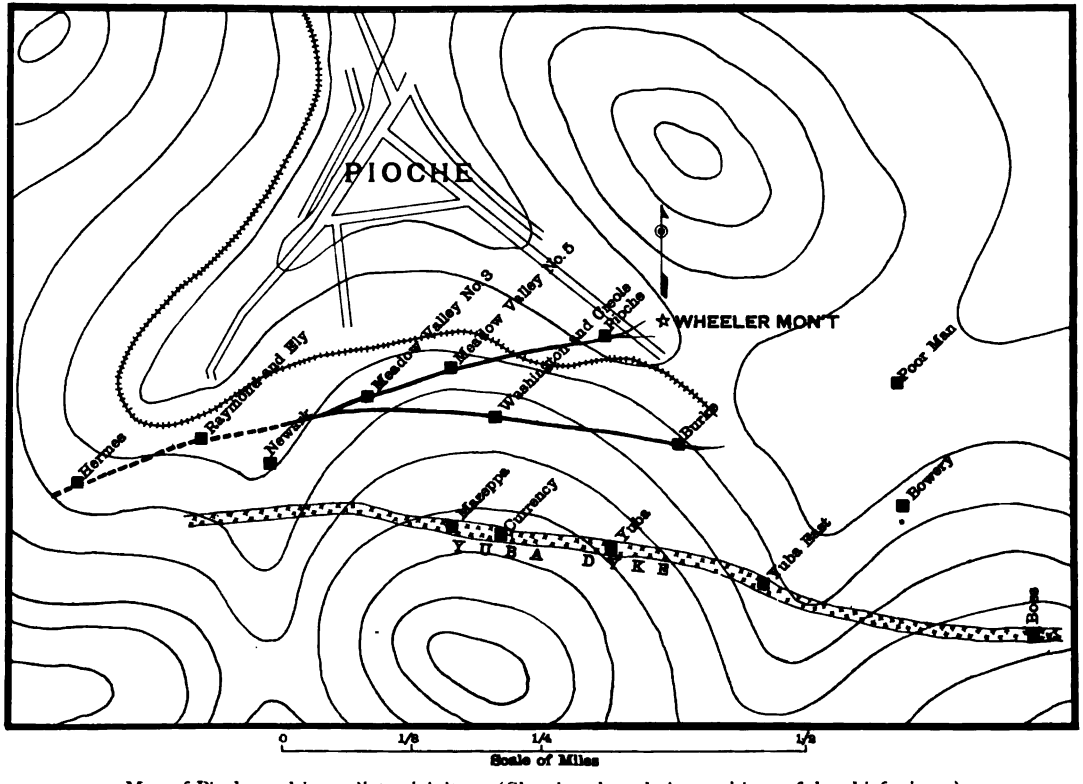
In describing the location of the various mines upon this deposit in 1872 Dr. R. W. Raymond imagines his reader standing at the point of bifurcation and facing the north. He then states: "Behind him rises the mountain, before and below him clusters the town of Pioche, and beyond that the wide prospect of a vast valley, bounded by mountains far away. To the right the two divergent branches of the vein are thickly set with shafts and hoisting works. They differ in their course by about 20 degrees. To the left (west) the single vein continues, barring a break, caused by a barren cross-course of brecciated material, mischievously interjected by nature to help the lawyers. The different claims lie on the surface as follows: West of the bifurcation the Meadow Valley Co. holds three hundred and forty feet; east of the same point the same company holds one thousand five hundred and twenty feet of continuous mining ground, through the whole of which the workings of the company extend, constituting a magnificent mine.

"Next to the Meadow Valley line on the west, comes the Panaca mine of the Raymond and Ely Company covering, I believe, six hundred feet, and containing the most remarkable body of high grade ore now to be seen on the coast.

"On the east, beyond the Meadow Valley line on the south branch we have the Washington and Creole, two hundred feet, and the Burke, Creole and Vermillion mines of the Raymond and Ely Company covering I believe, about one thousand five hundred feet.

Digitized by Google

Digitized by Google



Map of Pioche and immediate vicinity. (Showing the relative positions of the chief mines.)

Digitized by Google

On the north branch beyond the Meadow Valley line, comes the Pioche Company's ground about four hundred feet. Finally there are on both ends, and hovering about the claims enumerated, countless 'extensions' and adventures, which help to make things 'lively' in the district." The conditions described by Mr. Raymond are shown on plate VI.

The deposit is an ideal illustration of a true fissure vein. It outcropped for nearly half a mile and for two thousand feet of that distance it was mined right from the surface. The country rock was firm and stood well. Very little timbering was necessary. In consequence of this the workings are still open. One may now stand at the brink of this great chasm and see far down into the old workings, the vision being limited only by the darkness.

The vein material was quite silicious. The ores consisted largely of chlorides of silver and carbonate of lead, carrying a small amount of gold. Sulphides were occasionally seen even near the surface. The lead was generally present only in small amounts; it is assumed by Dr. Raymond that it did not exceed more than two or three per cent. The Meadow Valley Company, however, found one body containing nearly five thousand tons of almost pure lead carbonate.

By far the greater part of the production of the district has come from this vein alone. The Burke mine was the first located upon it, in fact it was the first in the district. Pay ore encountered at the surface was followed to a depth of about three hundred feet; beyond that point no valuable deposits were discovered.

The Meadow Valley Mining Company opened large and almost continuous bodies of high-grade ore throughout the entire length of their property. The vein was worked down to the twelve-hundred-foot level at which point water was encountered. The ores, however, decreased both in quantity and value beyond the eighth level.

On the Raymond and Ely property at the west the vein does not outcrop, but a shaft sunk for one hundred feet through the surface shale struck the ledge and developed the greatest bonanza of the district. The length of the ore body at the fifth level was nearly six hundred feet; it was almost continuous from the surface and varied from one to four feet in thickness. The ore consisted of carbonate of lead and sulfides of silver; it averaged $150 per ton.

Digitized by Google

The vein as a whole yielded its greatest values between the surface and the eighth level, below which the ores gradually became poorer. As water level was approached the oxides gave place to sulphides and large amounts of zinc also entered. At this depth the vein was generally strong and persistent, but no valuable deposits were in sight when the property was abandoned, even though prospecting had been very extensive.

A body of basic ore was encountered just below water level on the Raymond and Ely ground, but this was apparently on the dyke and will be mentioned in connection with the contact deposits.

The Contact Deposits.

All of the deposits considered under this heading are not strictly contact deposits, as some of them occur partly if not wholly within the igneous body. The Yuba Dyke, with which these ore bodies are associated, is situated far up the hillside south of Pioche, and in general is parallel with the Raymond and Ely-Meadow Valley fissure vein. A glance at Plate II. will make this matter clear.

Prior to and perhaps contemporaneous with the introduction of the ores the dyke suffered greatly through faulting, which in some places is confined to one contact and again to the other. Sometimes both contacts are faulted with an additional fracture or displacement within the intrusion. In the Yuba East property this fissuring has arranged itself into a parallel series extending diagonally across the dyke, and so constructed that a cross-section of this body at any point will show not less than two fissures and in most cases three.

The average thickness of the dyke is probably not more than seventy-five feet, and as a whole it is very highly fissured and faulted. This is probably the result of the somewhat sudden cooling to which so small a body would be subjected. In some parts the whole intrusion has become impregnated with silver and lead values. Indeed, assays of the rock almost invariably show the presence of these metals, and especially near ore chutes.

Most of the ore bodies are unlike true contact deposits in that they frequently penetrate the dyke and sometimes pass through it

Digitized by Google

FIG. 1. View looking north-east along the R. & E. fissure vein. The Raymond & Ely mine is in the foreground; the Meadow Valley No. 3 and No. 5, are in the distance.

FIG. 2. Meadow Valley mines. The vein was worked from the surface to a depth of 1,200 feet. The great fissure thus formed is still open.

Digitized by Google

Digitized by Google

and join with similar deposits on the opposite side. They are decidedly irregular and occupy the fissures occasioned by the shrinkage of the intrusion. Not a single instance has been recorded of these deposits entering the adjoining quartzite.

A few fairly typical contact deposits have been found; it was from these that the greatest values were obtained. They outcropped on the surface and extended to a depth of several hundred feet.

The eastern extension of the dyke has not been found far beyond the Boss mining claim. From this point it may be traced to the westward, passing the following mines, all of which are situated upon it: Yuba East, Yuba, Currency, Mazeppa, and Williams. Among these the Yuba and the Mazeppa have been the greatest producers, both of which have been sunk to a depth of nearly thirteen hundred feet. The Williams mine contains both a contact deposit and a cross fissure.

It should also be noted that a large quantity of ore was extracted from the so-called New York ore chute. This was a contact deposit and was mined through the Raymond and Ely workings about 1890.

In this connection attention should also be called to the body of basic ore struck below the twelve-hundred-foot level in the Raymond and Ely mine. According to Mr. Earnest Godbe, this is associated with the Yuba dyke, which was encountered a few hundred feet to the south of the fissure vein. He states that a winze has been sunk upon it for three hundred feet and that the ore body is continuous for that distance. Very little water occurs in this winze, even though it is lower than the flooded workings on the fissure.

The value of the contact deposits was not recognized in the early days, and consequently but very little work was done upon them. They were developed largely by W. S. Godbe about 1890 and since then they have been idle. The Yuba East property has recently been reopened, and now some fairly good ore bodies are in sight.

The Bedded Deposits.

So far as known the bedded veins occur in but three places, at the Mendha mine, at the Point mine, and in the vicinity of the Abe Lincoln-Half Moon mine. The first two are in limestone and the last one is in shale.

Digitized by Google

The Half Moon-Abe Lincoln ore body is in most respects a typical example of bedded deposit. It differs from others in its containing larger veins and in its stratigraphical position, but otherwise it is quite similar. The vein lies within a layer of shale some seventy-five feet in thickness, which is bounded both above and below by limestone. The thickness of the vein averages probably twelve inches. The ores are silicious. The values consist chiefly of carbonate and sulphide of lead carrying silver and a little gold. More sulphides were encountered in this class of vein than elsewhere at a similar horizon.

This property has been worked intermittently since the early seventies. The Abe Lincoln mine, which differs from the Half Moon in name alone, was being worked a year ago. The ores were milled and then subjected to cyanide process, but through some deficiency in the treatment the values were not extracted and operations were temporarily suspended.

The most striking feature of the deposits in the shale is their persistency. They may often be followed for several hundred feet with no appreciable variation in thickness. About a mile north of the Half Moon mine Messrs. Bingham and Welland have drifted on one of these for nearly five hundred feet, and have revealed a vein some ten inches thick throughout the entire distance.

This peculiar feature has led many of the miners to believe that the origin of the ore seam is similar to that of any sedimentary stratum, a view which of course cannot hold. It is not clear just why the mineralization should have been confined to a narrow zone apparently similar in composition and structure to the material both above and below. Our theories concerning ore deposition lead us to the conclusion that circulating solutions are largely if not wholly responsible for these deposits, and still it is quite impossible to believe that such solutions would influence a single layer for several hundred feet laterally, and yet not affect the material only a few inches above or below, unless for some reason this zone was particularly favorable to the circulation of the mineralizing agent. While it is freely conceded that circulation will ordinarily take place much more readily along the beds than across them, yet it is hardly possible in this case that the difference is sufficiently great to account for the facts. It appears that the deposits should be much more irregular than they are, even if the vertical passage of the solutions were confined to the pores of

Digitized by Google

the rocks, leaving out the undoubted existence of cross jointing.

At least a partial solution of this problem was suggested to the writer through a study of the ore bodies at the Mendha mine. The fissure vein at that mine has been faulted by a series of movements along the bedded planes of the limestone. Mineralization has subsequently taken place along these planes, so that they are now marked by a bedded ore deposit.

The ore bodies at the Point mine are of the same general nature, and due to the same cause. Faulting between the limestone layers accompany the anticlinal uplift, and circulating solutions later found ready passage along these planes. Both these deposits and the ones at the Mendha property are almost wholly the result of replacement.

After the unmistakable cases of faulting at the Mendha and Point mines had been studied the writer was fully convinced that the ore bodies of the Abe Lincoln type were also deposited along fracture or fault planes. They were then examined with this thought in view. The evidence was conclusive; in places simple fracturing had occurred with no apparent faulting, while in others actual thrusts had taken place.

It appears, then, that these bedded deposits mark the position of the fracture and fault planes which were formed between the beds during the anticlinal movement. Circulating solutions encountered very little resistance along these planes, and, therefore, formed thin deposits extending over large areas.

These ore bodies illustrate the stages of replacement in the simplest possible manner. The central part of the vein is fully mineralized, while on either side every point in the process is well shown. The accompanying photograph of a piece of ore taken from the Abe Lincoln mine still shows the shaly structure with remarkable clearness. (See Plate VIII., Fig. 1.)

The cause of this fracturing and faulting is an interesting subject. The Pioche anticline is composed of a core of quartzite overlain by shale and that in turn by limestone, which in a few places is interstratified with bands of shale. Some of the phenomena accompanying anticlinal movement may be illustrated by folding a pack of cards. It will be observed that each card slips on the adjoining one, and, further, that each one *rides up* on the one next lower. Two points are worthy of emphasis; first, that the

Digitized by Google

movements all occur along planes of weakness, and second, that these movements are all of the *reversed* order.

The writer is not prepared to assert that all such faulting will be of this class. A breaking down of the arch during the early stages of an uplift might render the conditions quite different, but in every case examined where movements were actually in evidence not one was of the normal type.

Now, then, in the case of the Pioche anticline the fracturing and slipping would occur along the planes of greatest weakness. Both the quartzite and the limestone are compact and massive, while the shale is very easily broken along its bedding. There appears to be no doubt that during the process of folding that the shale was thus fractured.

While it appears that the fissures now marked by the bedded deposits were formed in the early stages of the anticlinal movement and before the arch gave way, yet it does not follow that the introduction of the ore immediately succeeded. It is true, however, that the ore bodies show evidence of considerable age. They were involved in the general faulting which occurred long before the present topography was outlined. The age of the ore bodies is discussed in another part of this paper.

Age of the Ore Bodies.

Under this heading the longitudinal and transverse fissure veins will be considered together; the bedded and the contact deposits separately.

The Fissure Veins. — In the vicinity of Pioche the quartzite core has been thrust up between the flanking shale and limestone, and is now separated from them on both sides by a well-marked fault plane. This displacement occurred subsequent to the anticlinal movement. Indeed, its completion marks the last stage of that process, and yet, as shown elsewhere, there is reason to believe that the faulting is so old that the present topographic features were outlined quite independently of it.

The relative age of the ore bodies must be determined by comparison with the principal faulting.

The fact that the ore deposits are confined almost exclusively to the quartzite has lead to the belief that they were formed prior to the deposition of the superjacent shales. This cannot be the case, as their attenuated extremities have been traced into this formation

Digitized by Google

and also into the still higher limestone. And, further, there is complete proof of continuous deposition from the quartzite into the upper members.

At one time it was thought that the lateral extension of the ore bodies was marked by the two parallel faults which separate the shale and limestone from the quartzite. If this were true it would follow that the ore bodies are older than the movement which elevated the quartzite block. This, however, is not the case for the Raymond and Ely vein has been followed across the south fault into the quartzite normally subjacent to the shale.

Whether or not the vein was displaced by the fault cannot be specifically stated, as the mine workings are inaccessible and the desired data cannot be obtained from the records. The vein beyond the point of intersection does not outcrop, but the shafts sunk upon it are situated in the exact direction of its strike on the opposite side of the fault, a fact which indicates that the vein was not affected by the faulting movement. If the deposit had existed before this displacement occurred, it would have been heaved several hundred feet. It follows then that the Raymond and Ely-Meadow Valley fissure vein is younger than the movement which resulted in elevating the quartzite to its present position.

It is true that this vein has been displaced by one or more cross faults; it may also be the case that it has been fractured or perhaps slightly thrown by the northwest-southeast fault to which reference has just been made. This would not militate against the conclusion concerning the relative age of the ore body. A slight displacement of the vein could be explained by reason of the fact that old fault blocks frequently readjust themselves, even long after the principal movements have ceased. Nothing but a considerable heave could possibly be the result of the entire movement as the blocks were thrown fully one thousand feet on a plane which dipped sixty degrees.

The Bedded Veins. — These deposits show evidence of much greater age than the veins in the vicinity of Pioche. The ore body at the Half Moon mine has been thrown by one of the principal longitudinal faults which probably had its beginning back in the middle period of the anticlinal movements. The vein is also displaced by the cross fault that threw the Mt. Ely block down.

According to evidence elsewhere stated it appears that these deposits mark the positions of fault planes, which were formed

Digitized by Google

along the bedding as the folding of the anticline progressed. And from the above it is seen that they were displaced by the longitudinal faults. We may, therefore, feel reasonably sure that they were introduced soon after the folding process began.

The bedded veins at the Mendha mine occur along fault planes which were formed while the country rock was being folded. Concerning the age of this movement there is much uncertainty, but there is no evidence to indicate that it is recent.

The associated Mendha fissure vein was displaced by these faults, and is, therefore, older than the faulting. Nothing more definite can be stated.

The Contact Deposits. — The contact deposits in the vicinity of Pioche are found in association with the Yuba dyke. They occur within this igneous body as well as along the side of it, and were formed subsequent to its introduction. Moreover, the dyke cuts directly across one of the two principal faults, thus proving that its intrusion and the deposition of the associated ore bodies occurred since the upthrusting of the quartzite formation in which they are situated.

Therefore, the age of the contact deposits is the same as that of the neighboring fissure vein. The events discussed in the foregoing paragraphs appear to have occurred in the following order:

1. The anticlinal movement and the attendant shearing along the bedding planes of the shale.
2. The deposition of the bedded ore deposits.
3. The breaking down of the anticlinal fold.
4. The intrusion of the Yuba dyke.
5. The deposition of the fissure veins and the contact deposits.
6. The minor cross fissuring.

The anticlinal movement probably took place during the general elevation of the region at the close of Paleozoic time. No higher strata, however, than the Upper Cambric are now found in the anticline, the upper formations having been carried away by erosion. The Eocene deposits at the south of the Pioche Mountains have not been disturbed by any of these processes. It can only be stated, then, that these phenomena occurred between the close of Paleozoic time and the beginning of Eocene time.

Relation of the Ore Bodies to the Igneous Intrusions.

The early mine operators appear to have attached very little or no importance to the presence of the Yuba dyke, if, indeed, they

Digitized by Google

were aware of its existence. No allusion whatever is made to it in the early reports of the various companies. Prospecting was carried on apparently without even a general conception of the source of the ores; in fact, hundreds of holes were sunk where there were no "indications" whatever. Some little work was done on the dyke itself in the early days, and some very good deposits were uncovered, but the genetic value of this igneous intrusion was not realized until many years later. To-day the miner knows full well that it is quite unprofitable to prospect at any great distance from it.

It has already been noted that the mines at Pioche are grouped along the side of the Yuba dyke, none of them being situated more than one thousand feet from it, and many of them very much closer.

The great Raymond and Ely-Meadow Valley vein runs nearly parallel with intrusion; the two converge slightly toward the west, and, strange as it may appear, the nearer they approach each other the more valuable are the ores. This increase of values toward the intrusion is shown in the fact that the production of the Pioche mine, away out on the extremities of the vein, was only fair, while Meadow Valley No. 5, which was still closer to the dyke, was much better. Meadow Valley No. 3 was still richer, and the Panaca claim of the Raymond and Ely Company was by far the greatest producer of the district, and in its southwestern extension it came almost into contact with the dyke.

Another noteworthy feature is that the cross fissures are unprofitable except near their intersection with the dyke. A typical example of this is the Mike Williams property, situated immediately south of Pioche. This vein cuts the dyke at an angle of, say, 45 degrees. It has been very profitably worked near the intrusion, but away from it in both directions the values suddenly disappeared.

The relation of the fissure veins to the dyke is also shown in the fact that they approach each other in depth. The dyke dips to the south at an angle of 80 degrees; the vein dips in the same direction at an angle of 70 degrees. This means that if the dips remain constant these bodies will unite in depth, possibly somewhere between fifteen hundred and two thousand feet. See Fig. 8.

At the twelve-hundred-foot level in the Raymond and Ely workings a drift was run from the vein to the dyke, which at this depth was very much closer to the vein than at the surface.

Digitized by Google

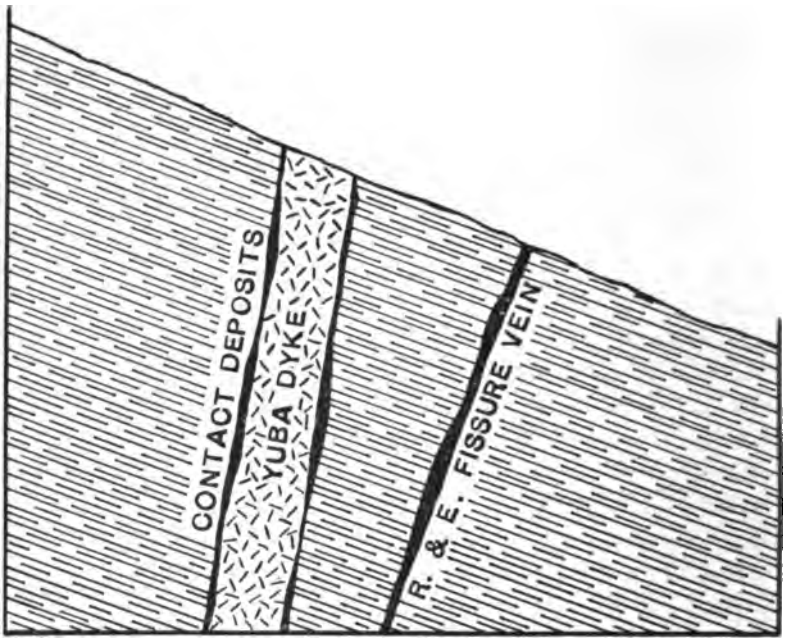


FIG. 8. North and south section across the Yuba dyke and the R. & E. fissure vein. (Showing that the two approach each other in depth.)

The fact should not be lost sight of that the deposits on the dyke itself have added largely to the production of the district. The ores had every evidence of coming from the same source as those in the fissure veins. They were high in silver and carried some lead and gold. It is true that the lead values were proportionately a little higher than elsewhere and that there were more sulphides, but this is without doubt due to the fact that the intrusion is more basic as shown by the disseminated crystals of iron pyrite.

The western extension of the dyke in the Stampede Gap region has never been prospected, but surface indications are good. There is scarcely a distance of one hundred feet along its course that does not show mineral outcrop. Two shafts now being sunk in this section have very good showings.

The fissure vein at the Mendha property is also very closely associated with an igneous intrusion in fact the two apparently intersect.

Digitized by Google

The underground workings of the Alps mine reveal a close relationship of the ores with the dyke. The vein strikes east and west, outcrops on the surface, and dips slightly to the south. It has been worked through drifts run from a shaft at the north. At the three hundred-foot level a seam of silicious shale was encountered and the ore body was lost. A drift run through this member entered an igneous dyke immediately below the vein. A continuation

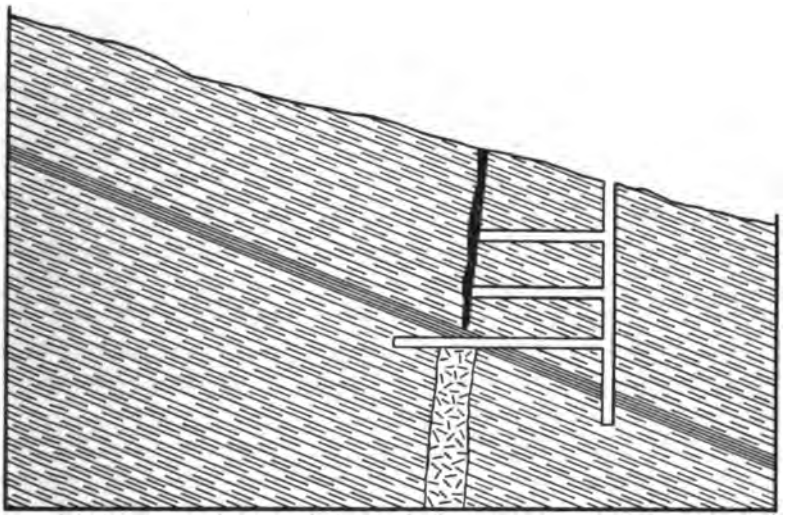


FIG. 9. Section at the Alps mine showing the relation of the ore body to the igneous intrusion.

of the ore deposit has never been found below this point, in fact little or no search for it has ever been made. The relationship of these various features is shown in the accompanying figure. The mine is situated in the direct line of the strike of the Yuba dyke at Pioche, but there are no igneous outcrops within half a mile of this property.

It is thought by one of the old mine operators that a fault has occurred along the bedding of the shale, and thus by chance the dyke and vein have been brought opposite each other. According to his view this has occurred since the deposition of the ore. A careful search was made for evidence of movement, but none was found. The vein is very much shattered and begins to pinch out at a considerable distance above this point. It appears that the

Digitized by Google

present relation of the vein to the dyke has not been changed since the introduction of the ore.

PROCESSES OF MINING.

The principal mining of the district has been confined to the quartzite, which as a rule is strong and massive. Some shattered zones were encountered, but in the main the walls were sufficiently strong to stand without support. The veins within the quartzite were all nearly vertical, and none of them were very wide. Timbering was quite unknown. The mines were all dry, and, therefore, not subject to the destroying action of percolating waters. The writer entered some of the old workings of thirty years ago, and found the walls still standing and generally well preserved. Very little crumbling has taken place even in that time.

The method of working the vertical veins was simple. The shaft was kept ahead of the drifts, which were run at convenient levels and the ore stoped down in the usual way. Many of the workings reached directly to the surface, and in these the men had to be protected from falling material, by means of planks placed upon cross stulls above them. Otherwise, except in the shafts, timbers were seldom used.

The contact deposits were mined in nearly the same manner. Timbers were not generally used, although they were required more frequently in the dyke material than elsewhere.

The bedded veins were thin, and it therefore became necessary to take out some of the wall rock with the ore. They were mined much the same way as coal seams; pillars were left at proper intervals for support. It is really surprising to see the great areas of unsupported roof that have stood for the past thirty years.

As a whole the matter of mining was a rather simple one. The ore bodies were not over large; the wall rock was firm and until the lower levels were reached there was no water.

The accompanying table gives a fair idea of the cost of mining. While at first sight the figures may appear high, yet it should be remembered that the work was done under very unfavorable conditions. The railroads were nearly three hundred miles away; freight rates on supplies were excessive and labor could almost demand its own price.

The low rate of extraction of the Raymond and Ely Company in 1872 marks the time when the great bonanza was being mined.

Digitized by Google

The highest cost for both companies occurred in 1874. This was brought about by the protracted litigation and its accompanying evils. The mines were fully patrolled by men commanding $20 per day.

COST PER TON OF MINING.

Year.	Company.	Extracting.	Prospecting and Dead Work.	Incidentals.	Total
1871	Meadow Valley.	$14.20	$5.71	$4.59	$24.50
1872	" "				38.55
1872	Raymond & Ely.				14.45
1873	" "	13.67	12.19	5.97	31.83
1874	" "	23.06	50.06	6.13	79.25
1874	Meadow Valley.	22.19	48.87		71.06
1875	Raymond & Ely.	14.78	20.18	10.14	45.10

During the year 1875 the rate again dropped, but this is rather deceptive as by far the greatest amount of dead work was done during that period. Nearly two hundred and seventy thousand dollars were spent upon these operations alone. The production in tons was very high but came largely from bodies of low grade ore which had been previously blocked out. The average yield of these ores was $52.36 per ton against a cost of mining of $45.10. Scarcely more than sixty per cent. of the values were recovered in the mill.

PROCESS OF REDUCTION.

The ores consisted chiefly of chloride of silver and carbonate of lead with some sulphides of these metals. They usually carried about one dollar in gold to twenty dollars in silver. There were two classes, one described as "free" and the other as "base." The values of the first were chiefly in silver, of which approximately 80 per cent. was the chloride. The base ore carried both lead and silver in varying proportions. In this the silver values were about 45 per cent. chloride and the rest probably sulphide and oxide. By far the greater part of the ores of the district belonged to the class described as base.

During the winter of 1869–1870 a smelter was built for their treatment, but it proved a failure because of the small percentage of lead present.

It was then learned that the "free" ores would yield their values readily by the process of pan amalgamation, but from the "base" type not more than 50 per cent. could be recovered by

Digitized by Google

this method. Alix Janin, of White Pine, was finally successful in demonstrating that the latter would amalgamate freely when salt and copper sulphate were used with the charge in the pan before the introduction of the mercury.

Early in 1870 the Meadow Valley Mining Company erected a twenty-stamp mill at Dry Valley, ten miles to the east of Pioche, where there was a good supply of water. Later ten more stamps were added. Salt and copper sulphate were used in this mill with very satisfactory results. About 80 per cent. of the values were extracted when these chemicals were used compared with 60 per cent. without them.

The lead was separated from the bullion by passing the mercury and amalgam through a sack suspended in boiling water. The lead amalgam being liquid at this temperature passed through the sack with the mercury, leaving the amalgamated silver behind. These products were in turn retorted in the usual way, resulting in two grades of bullion, one about 750 fine and the other about 100 fine.

In the fall of 1869 W. H. Raymond constructed a small five-stamp mill at Bullionville, near Panaca, and some eleven miles to the south of Pioche. When he first began operations he treated the base ores without chemicals. The result was that he extracted less than forty per cent. of the values. Later the character of the ores changed and the results were much more satisfactory. Still later salt and blue stone were used as at Dry Valley.

Bullionville soon became the milling center of the district. The Raymond and Ely Mining Company had at least two mills here; one a twenty-stamp wet crusher and the other a thirty-stamp dry crusher, which was later converted into a wet crusher. W. H. Raymond put in another mill of ten stamps, and the American Flag Mining Company one of twenty stamps. Besides these there were some others of varying degrees of merit and success.

It was necessary to locate the mills at Bullionville because of the aridity of the country in the immediate vicinity of the mines. The expense of freighting the ores from mine to mill ate largely into the profits. A project for connecting these places by rail was completed some time in the latter part of 1872 or in the early part of 1873. Engines, cars, rails, and in fact all equipment had to be freighted by team from distant points in Utah, but this great expense was soon returned in the saving of freight rates.

Digitized by Google

FIG. 1. Ore from the Abe Lincoln mine. (Showing various degrees of replacement.)

FIG. 2. Practically all that remains of Bullionville.

Digitized by Google

Digitized by Google

Bullionville in the early seventies was one of the busiest towns in the far West. To-day its site is marked by a single smoke stack, some dumps, and a few crumbling walls.

Since it was abandoned a large part of the old mill dumps have been reworked. Just how much was recovered from them can hardly be even approximated, but old miners claim that it approached a million dollars.

It now remains for some one to sample the portion of the dumps that have not been reworked and to install a plant suitable for the extraction of the remaining values. Such an enterprise should be followed by profitable and quick returns.

PRODUCTION OF THE ELY MINING DISTRICT.

The accompanying statistical tables show in a general way the commercial importance of the district during its period of production. They are taken from the reports of the United States Commissioner of Mining Statistics. It is hardly possible that the data here given represent the exact conditions, but none better are available. A few discrepancies are apparent; for instance, Table No. 1 shows no assessment against the Meadow Valley Company for the year 1875, while No. 2 shows one of $30,000 as late as December of that year. The latter also has an item of $1,290,000 as total assessment against $210,000 in the former. It is probable that the larger amount more nearly approaches the truth, as enormous sums are known to have been levied during this the last year of the company's existence.

At first thought it may appear that all of the mining enterprises were failures with the exception of the Raymond and Ely. While this appears to be the case, yet it is misleading. Enormous bodies of high-grade ore were encountered in several of the mines; if the present facilities for mining and reduction had been available the outcome would have been far different. The failures, therefore, ought not to be attributed wholly to the paucity of ore bodies, but rather to the conditions under which they were worked. It is true that many fortunes were spent in barren ground, but the enormous production of such mines as the Raymond and Ely and the Meadow Valley places them among the foremost silver producers of the West.

Digitized by Google

TABLE I.

Year.	Company.	Bullion Receipts.	Dividends.	Assessments.
1870	Meadow Valley	$644,719		$210,000
1871	Meadow Valley	1,753,708	$330,000	
	Pioche	203,537	20,000	20,000
	Raymond and Ely	1,361,628	615,000	
	Washington and Creole			15,000
	Others			7,500
1872	Alps			37,500
	Bowery	36,485		52,500
	Hermes			30,000
	Huhn and Hunt	13,122		82,500
	Kentucky			15,000
	Louise			15,000
	Meadow Valley	1,303,537	690,000	
	Newark			40,000
	Page and Panaca			40,000
	Pioche	232,417	40,000	20,000
	Pioche West Extension			19,250
	Raymond and Ely	3,693,936	2,070,000	
	Silver Peak			15,000
	Washington and Creole	84,500		67,500
	Others			166,000
1873	Amador Tunnel	48,560		30,000
	Alps	28,177		105,000
	Bowery	4,000		30,000
	Chief of the Hill	36,814		45,000
	Hermes			60,000
	Huhn and Hunt			112,500
	Kentucky			75,000
	Newark	128,528		73,600
	Meadow Valley	738,646	240,000	
	Page and Panaca			40,000
	Pioche	72,190		70,000
	Pioche Phœnix			40,000
	Pioche West Extension			17,500
	Raymond and Ely	2,339,364	390,000	
	Silver Peak			37,500
	Washington and Creole	66,687		60,000
	Others	259,064		485,800
1874	Meadow Valley	471,958		
	Raymond and Ely	673,051		180,000
	Others	756,205		
1875	Meadow Valley	82,168		
	Raymond and Ely	738,305		330,000
	Others	229,698		

Digitized by Google

TABLE II.

TABULAR STATEMENT OF ASSESSMENTS AND DIVIDENDS, FROM THE DAILY STOCK REPORT ASSESSMENT-LIST, SAN FRANCISCO, JANUARY 17, 1876.

Companies.	Number of Assessments	Number of Shares in Mine.	Last Assessment Levied.	Amount per Share	Number of Dividends	Last Dividend.	Amount per Share.	Total Amount of Assessments Levied.	Total Amount of Dividends Levied.	Amount of Assessment per Share	Amount of Dividend per Share.
American Flag.....	7	40,000	Mar. 26, 1875	$0.50				$260,000		$6.50	
Alps.....	8	30,000	Feb. 10, 1875	25				105,000		3.50	
Bowery	6	30,000	Dec. 15, 1874	20				94,000		3.15	
Chapman	4	30,000	July 28, 1873	25				37,500		1.25	
Chief of the Hill.....	6	30,000	Mar. 26, 1875	25				75,000		2.50	
Condor	4	25,000	July 9, 1875	50				50,000		2.00	
Huhn and Hunt.....	11	30,000	May 7, 1875	50				294,000		7.55	
Ingomar	7	40,000	May 4, 1874	25				70,000	$50,000	1.75	
Louise	3	30,000	Sept. 15, 1872	50				21,000		70	
Meadow Valley.....	10	60,000	Dec. 28, 1875	50	17	June 16, 1873	$1.00	1,290,000	1,200,000	21.50	$20.00
Newark.....	12	32,000	Sept. 14, 1875	50				304,600		9.55	
Page and Panaca	8	40,000	Oct. 6, 1874	75				190,000		4.75	
Phoenix.....	14	50,000	Apr. 21, 1874	50				337.500		6.75	
Pioche	11	20,000	Dec. 1, 1875	50	3	Aug. 5, 1872	1.00	230,000		11.50	3.00
Pioche West Extension	8	35,000	July 12, 1875	2.00				171,000		4.90	
Portland	5	30,000	Aug. 21, 1874	25				71,000		2.36	
Raymond and Ely.....	5	30,000	Nov. 5, 1875	3.00	23	Sept. 10, 1873	3.00	510,000	3,075 000	17.00	102.50
Silver Peak	6	30,000	Mar. 29, 1875	50				105,000		3.50	
Silver West Consolidated ...	5	50,000	Dec. 7, 1875	10				42,500		85	
Spring Mountain Tunnel.....	9	20,000	May 22, 1874	10				33,000		7.35	
Washington and Creole.....	15	30,000	Sept. 27, 1875	75				315,000		10.50	
Watson.....	1	30,000	Nov. 16, 1874	1.00				30,000		1.00	

Digitized by Google

THE HISTORICAL DEVELOPMENT OF GENERAL CHEMISTRY.*

By WILLIAM OSTWALD,
Professor at the University of Leipzig.

Fifth Lecture. Equilibrium and Chemical Affinity.

Ladies and Gentlemen: In the beginning of the nineteenth century, the text-book of chemistry which was most used in Germany was one written by von Stahl, the same man who was the originator of the phlogiston theory. From our previous description of the phlogiston theory you will see that von Stahl was indeed a man of the most systematic mind, for he knew how to find the general truth connecting a number of the different factors.

In this same text-book of von Stahl's you will find a page dealing with a most peculiar regularity, one which was first recorded by him. If you dissolve silver in nitric acid (of course, I could take any other example) and add metallic copper to it, the copper will throw out the silver, *i. e.*, the silver will reappear as a metal and copper will go into solution. If a piece of metallic lead is now brought in contact with the solution it will throw out the copper, and take its place in the solution. And from this solution we can again obtain the lead by treatment with metallic zinc. Further, the zinc solution can be precipitated by throwing in some lime, and from the lime solution you can precipitate the lime, *i. e.*, as carbonate of calcium, by adding carbonate of ammonium, which was a well known preparation at that time. And, finally, by treating this solution in its turn with potash, and heating, the ammonia can be expelled. In this way we find that there exists a series of different compounds and different substances, or elements, as they were considered at that time, which is so made up that each succeeding member in the series will throw out or precipitate or cancel from the combination the previous members. von Stahl especially pointed out in this connection that the third or fourth member

*Course of six lectures delivered in the Department of Chemistry of Columbia University, Havemeyer Hall, January 26 to February 2, 1906. Reported stenographically. Lectures 1 and 2 were printed in the January, 1906, number; lectures 3 and 4 in the April, 1906 number. Copyrighted by the School of Mines Quarterly.

Digitized by Google

will throw out the first, just as in our example the second member did. This series was called later the series of affinities.

von Stahl laid great stress on these facts and particularly recommended his readers to consider the series and the facts connected with it as exhaustively as possible, because the great secret of chemistry lay hidden in it. This idea of a series of affinities or a series of reactions of a similar kind was then taken up in a later time by the French chemist Geoffroy, who did not add much to this idea of von Stahl's, but simply tried to arrange all known substances (there were not very many at that time) into such a series, which he published as an affinity table. In the history of chemistry you will find that Geoffroy, only, is mentioned as the inventor of the affinity table, although he simply acknowledged and amplified the older idea which belongs to von Stahl, so far as my historical investigations go. But, of course, it is not impossible that someone even antedated von Stahl in the recognition of the law, although if so I cannot find any mention of it.

Now investigation showed that such a simple table was not to be made; it appeared that several of the reactions that went on in a certain way in aqueous solutoins, or in the wet way, as it was called at that time, were to be arranged in an entirely different order when the substances brought into contact were not dissolved, but molten; so that instead of the one table of affinity it was necessary to construct at least two tables, one for reactions in the wet way and the other for reactions in the dry way, *i. e.*, produced by the application of heat.

And further, the number of known substances increased so rapidly that Bergmann, who tried to work out the whole chemical theory of these reactions of decomposition, found himself in the face of an overwhelming number of necessary experiments if he were to prepare a complete table of affinity which would explain or enable us to predict possible reactions. Of course, in addition to these there are many possible combinations between two known substances, and, as I remember, Bergmann computed the number of experiments necessary to be carried out to be 20,000 or so.

At the same time Bergmann tried to get a general expression for the behavior of chemical substances decomposing into others, and to express the general relations of these things. He considered that chemical reactions were brought about by the same

Digitized by Google

force which moves the heavenly bodies, by general attraction or gravitation, and concluded, therefore, that the method of investigation should be the same. If there were two different atoms, there must be a certain attraction between them. And if a certain atom intervened which has a stronger attraction to one of the two atoms than to the other, the stronger attraction must prevail, and the weaker atom be thrown out entirely, so that the new combination will contain only the atoms with the stronger attraction.

You see this is a very simple theory and proved sufficient and satisfactory at the same time, for it was then generally supposed that all chemical reactions took place in this absolute way. This was the state that existed at the end of the nineteenth century, and Bergmann's theory, as based upon these different attractions was quite well known. It was certainly a most picturesque theory, and if you would like to get a more detailed idea of it I would refer you to the work of Gerhardt, in which he uses this idea of Bergmann's of the mutual attraction of the different bodies, and describes with much vigor the irresistible force of their attraction, independent of any former union or former combination.

This theory looked beautiful, however, only because people omitted to consider the cases which disagreed with it, for it was found to be quite impossible to arrange all reactions in a systematic table; and, indeed, you will find in the periodicals of that time that even then a little fun was made of the authors of these inverted tables, although generally, it must be said, it was considered as the leading theory in chemistry.

Then a man, whose name I mentioned several days ago, made a considerable advance. This was Berthollet, who developed some new ideas of his own which proved much more exact and more fitted to the present facts than these older ideas of the relative affinity. Berthollet was induced to investigate these things by rather a rare circumstance. He was taken by Napoleon the First to Egypt in that romantic expedition at the beginning of Napoleon's brilliant career. Napoleon took care to take with him a great number of scientists to investigate Egypt in every line, and to contribute to his library beautiful large volumes descriptive of Egypt, which were later published by the French government. Berthollet, as one of this band of scientists, observed the formation of soda in the desert, *i. e.*, observed how it came out of the soil by drying, by efflorescence, being formed, evidently, from common salt. This

Digitized by Google

induced Berthollet to wonder how common salt could be changed by these natural circumstances into soda, and as a result of this he discovered that it was efflorescence that caused the salt to separate out. Then he worked along these lines, reading papers descriptive of his investigation in the Institute of Egypt, established by Napoleon at that time, and finally finding that there are quite a number of different cases where well known reactions could be inverted, *i. e.*, forced to take place in an inverse way.

And these facts induced him to entertain the following idea. He said those specimens of chemical affinity of the old chemists were due to mutual attraction or some similar reason, as gravity, but, just as two forces never destroy one another entirely, in the same way an antagonistic chemical force could not destroy another entirely, and some intermediate step between the action of the two forces must always result. If we have two acids, for example, fighting for an insufficient quantity of a base, it would not be like two dogs fighting over a bone, that one gets the bone and the other gets nothing, but each one would get a portion of it, the stronger acid getting the greater part and the weaker acid the lesser; but the weaker acid would never be dismissed without getting at any rate a little bit of the base.

By this general idea he explained precipitation and affinity. It is just as if we should describe in our time the influence of a new phase. You will remember the phases that we discussed in our first lecture. By the formation of a new phase the equilibrium existing in the first phase is disturbed, but the quantity of any phase does not change the equilibrium law. If, for example, we have a million pounds of ice and water in equilibrium, and take from the water or the ice, or add any quantity of water or ice, the equilibrium will not be disturbed. But if there are gases being given off in the form of bubbles, that gas will be leaving the field of battle, and not taking part in the formation of a new phase. A partition between the possible compounds, then, can be made to look like an absolute change, an absolute decomposition. He explained, for example, if you add some acid to a solution of carbonate of potash, there will be the partition of the potash between the carbonic acid and the acid, for example, acetic acid, but as the carbonic acid would assume the gaseous state and escape, the equilibrium would be disturbed. More carbonic acid will then be formed in the liquid, and be in its turn changed into the gaseous

Digitized by Google

state, and decomposition will continue until the whole quantity of carbonic acid, and the whole quantity of acetic acid is used up; and instead of the true equilibrium of separation we observe practically a one-sided reaction, but only because the carbonic acid is transformed into the gaseous form and escapes. In the same way a precipitation may be explained. If we add sulphuric acid to chloride of barium, both acids will take some of the barium for a time, but the sulphate of barium would leave the field of equilibrium again in the form of a precipitate, therefore the equilibrium is disturbed, and more sulphate of barium is formed, and so the process goes on and on until complete decomposition is the result. This, however, is not an absolute decomposition, because in the first case some, a very little, carbonic acid will remain dissolved in the liquid, and in the second a little barium sulphate.

Now all these ideas were quite right, and Berthollet, after publishing several papers, included them in his book Statique Chemique. Although in this most remarkable book Berthollet put all that he knew, and told it in a most systematic, scientific form, he succeeded in writing a most unreadable book. In fact, I think, there has never been a scientific book which has received so much praise, and yet been so little read as this very Statique Chemique. You know perhaps that I have been interested in just this question of equilibrium and affinity since the beginning of my scientific career, but I must confess that I never got so far as to read this whole book, and do not believe that I lost very much by not reading it, because the important things considered had already been brought out in his former papers, and it is only the peculiar systematization has made his work so good, and also so difficult to read.

Berthollet also tried in his book to prove the idea of constant proportions in chemical combinations, which I referred to in a former lecture, and it is probably due to the fact that his ideas proved erroneous in this line that people did not take much heed of his other ideas, for these were utterly neglected for a time.

One cannot blame the chemists very much for this, for besides the difficulties of Berthollet's teachings there was another reason which turned the scientists of his time away from his investigations. It was the discovery of the law of contant proportions and the law of combining weights, which occurred just at the time that the Statique Chemique was published, about the year 1803 or

Digitized by Google

1804, *i. e.*, just at the beginning of the nineteenth century. You will remember also that just a few years later, Dalton's views, and the discovery of Gay Lussac's law of the combining volumes of gas were announced, and chemistry was so busy with the working out of these most important new things that they forgot altogether to interest themselves in these much more difficult questions which were introduced by Berthollet.

Thus Berthollet and the question of chemical affinity disappeared entirely, for in order to apply these new things the formulas of all the substances known at that time had to be first obtained. And just as the bulk of this work had been done a new rush in scientific chemistry began in the development of organic chemistry, which went on in just the same line, closely connected with the atomic theory, as I explained to you yesterday, and not at all connected with this question of chemical affinity. Chemists in this line were only interested in discovering ways of preparing new substances, so that it made little difference to them whether the reactions went entirely to one side or not.

The only people who concerned themselves with the question of the chemical affinity were the analysts. The analysts were of course interested in the question of how exactly they could determine different substances. Substances were determined at that time, as now, by getting some precipitate which contained the substance asked for, washing, drying, igniting and weighing it. Therefore the question of the completeness of the reactions was of the utmost importance for the exactness of their results, and in this way the analytical chemists quickly discovered that the so-called insolubility of the precipitate was not insolubility at all, and that these reactions which had been regarded as complete were in many cases not at all complete; and that to make them even practically complete, it is necessary to alter the conditions. In other words, they observed that equilibrium was to be found everywhere.

Foremost in this work was Heinrich Rose, the man who first brought analytical chemistry into a systematic order (for before his time it was more of an art, while since then it has become a science). He published a large number of papers in which he showed, for example, that even a substance considered as almost absolutely neutral as water, could take a large part in chemical equilibrium. For instance, the alkaline borates decompose in water, and the greater the dilution the smaller the amount of boric acid remaining

Digitized by Google

combined. He also found that water can drive out the boric acid from combinations with other bases.

Then slowly, by more and more experimentation and observation in the same line, other facts came to light. It was slow progress until toward the last quarter of the nineteenth century. I cannot enter into the details of the investigations which showed more and more the fact that chemical equilibrium was a much more frequent thing than people had usually supposed, because as I have just pointed out the *practically* complete reactions are just as good as complete reactions, not only for analytical purposes, but, also for manufacturing purposes, and other reactions were not investigated because they did not give good results in the practical sense. Only very slowly more and more reactions were discovered showing rule of affinity to be just that which Berthollet has assumed the and described.

Then in the last quarter or last third of the past century, a new line of research began with a paper of two Norwegian scientists, one a chemist, the other a mathematician. Guldberg and Waage took up the idea of Berthollet, but added a very important thing, a mathematical theory of equilibrium. They started from a very simple assumption, namely, as they expressed themselves at that time, that chemical force is proportional to the amount of substance in the unit of volume, *i. e.*, to the concentration of the substance, and that when several substances are concerned in a reaction, the chemical force is proportional to the product of the concentrations of the several substances. If we have the reaction $A_1 + A_2 = B_1 + B_2$, where A_1, A_2, B_1 and B_2 represent chemical substances, then, representing the concentrations by the letters a_1, a_2, b_1 and b_2, according to Guldberg and Waage, we have the relation $K_a a_1 a_2 = K_b b_1 b_2$.

If equilibrium exists, of course, the amount of force on both sides is the same, and we have

$$\frac{a_1 a_2}{b_1 b_2} = \frac{K_b}{K_a} = \text{constant.}$$

This is a very simple idea of Guldberg and Waage's, and they showed in a number of instances that it would always hold good, and express any chemical equilibrium by a simple equation. This was a starting point for new discoveries, and the law of Guldberg and Waage, as it is called, has w n it s lf, indeed, as the general

Digitized by Google

law for chemical equilibrium, only a slight alteration being developed at a later time. This I shall return to later.

By his work in thermochemistry a man named Thomsen confirmed this law of Guldberg and Waage, and, slowly, an increasing number of different scientists recognized that it was a most important and general law, *i. e.*, was the law of chemical affinity.

Along the former line of development I should like to mention here still one name, or a couple of names; those of Berthollet and Péan de St. Gilles. These men published some time before this a paper about the reaction between alcohols and acids, and between esters and water, and observed large numbers of cases of chemical equilibrium which could be investigated easily. In their paper, consequently, there is a large amount of numerical material for the testing of this simple law of equilibrium. They had a theory of their own, also, but they did not succeed so well as Guldberg and Waage, who should be considered as the first discoverers of this general law of equilibrium.

For the sake of historical completeness I would like also to mention here the names of two other scientists, again a chemist and mathematician, Harcourt and Esson, who were busy with the same task, and who also found the same law, in a somewhat different way, through the consideration of chemical velocity; a matter we shall discuss in our next lecture.

All these investigations brought about the same result.

In the meantime, quite another series of ideas had developed, those from the side of physics. One of the most important parts of physical science is thermodynamics, but which I would prefer to call energics, because it has to do with the transformation of one kind of energy into any other, not only the transformation of work into heat or consversely, although these investigations confined themselves at first mainly to the questions concerning the transformation of heat into work. Indeed the first leaders in this development, Clausius and William Thompson (Lord Kelvin) did not vex themselves with chemical questions; there is very little to be found about chemical questions either with Clausius or Lord Kelvin; but a young chemist, who was a pupil of Clausius, at once tried to apply the laws of the thermodynamics or the laws of energetics to chemical questions, and he was the founder of this idea that energetics concerns itself with chemistry. His name was Horstmann. He was the first to apply the formula of thermodynamics

Digitized by Google

to chemical problems, and he got for chemical equilibrium just the same equation as Guldberg and Waage, and found it to agree well with experiment. I wrote the equation above in a way which would not fit every reaction. For example, if you investigate the decomposition of carbonate of lime by hydrochloric acid, you must write one carbonate of lime and two hydrochloric acid to give the equilibrium. The outcome of Horstmann's investigation, which was concerned only with gases (for dynamical equations were only known for gases and not for liquids, and still less for solids), *was that the number of molecules, or number of units concerned in the different gases in the action, must be used as exponents of the concentrations.* Horstmann only found two or three gaseous reactions, by the aid of which he could test this formula; but the results of these tests were quite satisfactory, although limited, for by far the greater number of reactions are those between liquids or liquids and salts.

Now just at this time there came the discovery I told you about two days ago, the discovery by van't Hoff, that the law obtaining for gases is applicable also to dissolved substances of any kind, provided instead of the simple gaseous pressure the osmotic pressure of the solution is taken into consideration. This meant an enormous extension of the importance of this thermodynamic law, for instead of the few cases of chemical reactions between gases, which could be observed and studied, there are an unlimited number of chemical reactions taking place in solution which can also be studied in the light of the formula of Guldberg and Waage or Horstmann.

Another fact, one which was also mentioned two days ago, is the fact of the independence of the behavior of the ions. You will remember that by the application of van't Hoff's law of osmotic pressure to the solution of salts some difficulty was encountered so that van't Hoff introduced a factor into his equation for salts to indicate the behavior of these substances and Arrhenius showed that just these solutions were separated into their constituent — the ions.

Now these ions of the dissolved salts were next considered as independent substances in the equation as expressed by Guldberg and Waage, and Horstmann, and the result was a perfect one, so that the number of cases which could be treated by the law of chemical equilibrium was enormously increased. Finally, it was found to be applicable to almost every solution, and not only to the solution of salts. In other words, the whole of analytical chemistry was

Digitized by Google

found to be governed by the law of equilibrium, and the attention that analytical chemists have paid to the fact of equilibrium, has helped largely in the great development which analytical chemistry has obtained by the application of, first, the law of affinity and, secondly, the notion of osmotic pressure and ionic or electrolytic dissociation.

It would take not only the remainder of this lecture but a regular course of several lectures a week through the whole academic year, to explain and develop all these applications of the laws of electrolytic dissociation and osmotic pressure in analytical chemistry, but just to show you what is meant by this development, let me explain one other case which is important and interesting from the chemical and analytical standpoint.

I will describe to you an experiment which is rather startling for a man not versed in these modern considerations. If you add to a solution of sulphate of iron, simply a neutral solution of iron, a small quantity of acetic acid, you can treat it with hydrogen sulphide without causing any precipitation of sulphide of iron. From a quite neutral solution some of the sulphite would precipitate, but if the solution is acidulated with acetic acid no precipitation ensues. But if you let fall into the liquid a small piece of sodium acetate it will carry with it as it sinks a long black tail, which is sulphide of iron. In other words, just by the addition of this neutral salt, the iron will be precipitated in the solution in which it was not previously precipitated. I think, according to the old idea of chemistry, this would be rather a difficult thing to explain. I will now show you how it is to be explained at present.

We shall write acetic acid as AH, A meaning the negative radical of acetic acid CH_3CO_2—and H meaning hydrogen. Now, according to the idea of electrolytic dissociation, if we dissolve acetic acid in water it splits up into hydrogen-ion and acet-ion. I will indicate hydrogen-ion by a dot and acet-ion by an accent, and write the reaction

$$HA = H^{\cdot} + A'$$

Now if we apply the law of Guldberg and Waage, indicating the concentration of acet-ion by A, that of the hydrogen by H, and that of the unionized acid by HA, we obtain at once the equation

$$\frac{A \cdot H}{HA} = C,$$

Digitized by Google

a constant. In this way it is possible to calculate the degree of dissociation of the acetic acid. I cannot explain here, of course, the methods by the measurement of electrical conductivity. You can take any solution of acetic acid more or less concentrated, up to the last degree of concentration, and you will find that the relation above will hold good for all, even to the most dilute solution which can be investigated. Therefore, the addition of acetic acid to our solution of iron sulphate brings hydrogen-ion into the solution, *i. e.*, some free acid, and you know, of course, free acid prevents the precipitation of iron sulphide, so that nothing happened. By the addition of sodium acetate to this solution, however, since sodium acetate contains acet-ion (it is almost entirely dissociated into its two ions in a dilute solution) we increase the amount of A, *i. e*, we increase the concentration of the acet-ion in the solution; therefore to obtain the same value of C as before, the concentration of hydrogen-ion must decrease in the same way as A is increased, then C remains constant, but this means that simply by the addition of the neutral salt to the acid solution the concentration of the hydrogen-ion in the solution is largely decreased, and therefore cannot prevent any longer the precipitation of the iron sulphide.

This quantitative relation has been tested in a great number of cases and has been found to hold good in by far the most cases. There is more difficulty, as you know, with strong electrolytes, but I have just received the news that nitric acid has also been proven to follow the law.

I am sorry we cannot go deeper into these details, but I believe I may surely point out that analytical chemistry obtained an entirely new lease of life by the introduction of these theoretical considerations, *i. e.*, by the introduction of the ideas of electrolytic dissociation and osmotic pressure.

To give you an idea of this I shall simply point out to you one or two other facts. You know from analytical chemistry that all copper salts give the same test for copper; this is quite independent of the nature of the salt; it does not matter at all whether we have sulphate of copper or some unknown acid combined with copper; all solutions exhibit the same greenish blue color, and give the same test for copper, if pure. This is not so, for example, for every hydrogen compound, or for every nitrogen compound in organic chemistry, and in the past it was quite inex-

Digitized by Google

plicable. There is no such test for hydrogen compounds. You can test for nitrogen in ammonia, in hydrocyanic acid, and so on. Every one has a behavior of its own. There is no general test for these elements as for copper, chlorine, etc., in solution.

Now the thing results in a test as simple as you can imagine. In all copper solutions there is copper ion. We must assume that these ions are separated in a certain way in the solution, and have an existence of their own. And that is just the reason we can explain why copper gives the same test. It is dependent upon the ion present. The other ion is also present, but not combined with the copper ion, and does not alter its property.

This explains why we cannot find a test for iron in a solution of potassium ferro-cyanide. For investigation tells us that in potassium ferro-cyanide there is no iron-ion, for the iron forms part of a more complicated ion, the ferro-cyanide-ion, and therefore, we get no test for iron; for this is due to the presence of the iron ion.

The tests for these different ions are thus perfectly clear. The whole of analytical chemistry, in other words, is the chemistry of ions, and if the student knows the properties of the ions he can take care of all possible combinations between these ions. If he knows 100 different reactions he also knows 10,000. He does not have to learn every possible case, therefore, but simply the standard reactions of the various kinds of ions.

This means a large practical application of this modern theory; but it would lead us too far to go further into it now. The one thing I wish to point out at the conclusion of this lecture is simply that science is the most practical thing in the world.

SIXTH LECTURE. CHEMICAL DYNAMICS, INCLUDING CATALYSIS.

Ladies and Gentlemen: To-day we are to cut our last cross-section through the body of general chemistry. I am well aware of the large areas which have been omitted by this operation, *i. e.*, how large are the parts lying between the different sections I have made, but I have had to omit them, not because I consider them of less importance, for electrochemistry and thermochemistry are really most important parts of the body of general chemistry, but because they are situated too near the other cross-sections, so that we could not have obtained such a systematic view as we shall by the division I have had in mind.

The last cross-section is to consider the rate of chemical changes,

Digitized by Google

a question which we have met before in our investigations, *i. e.*, the question of chemical dynamics.

That time is necessary for the progress of chemical operations is, of course, our experience, but generally it seems to be more the mechanical result of lacking contact than anything else. For example, when a bit of wood or coal is burning, it does not burn all at once, because the contact between the solid material and the air is confined to the surface and the whole operation cannot go on anywhere else but on the surface where both substances meet. But time is necessary also in homogeneous reactions; we know such boundaries are in existence by our late experience, though we cannot see in our time why this experience came so late.

The first part of chemistry investigated was the chemistry of salts, or, as we would describe it now in modern terms, the chemistry of ions. Now it is a general law that reactions between ions take place so quickly that it is not possible to observe that they require time. We do not know anything about the time factor in these reactions, because we have no means of investigating this very quick chemical change. Therefore all chemistry so far as concerns salts or ions is, in such a sense, timeless, and no laws in regard to time reactions could be found at that time.

Only by the slow development of mechanical chemistry, where there are reactions taking an appreciable time, could the laws governing such time processes in chemistry be observed.

It is true that before this we find mention in the older writings of such reactions and their actual measurements, but these begin only in the middle of the last century. The first remark I find in the history of the science was one in a book by this man, Wenzel, whose name you will remember from the mistake of Berzelius, who quoted him instead of Richter. Now, as I told you then, Wenzel was a rather advanced chemist for his time, and was the first man to express the general law of time action. So early in the last quarter of the eighteenth century Wenzel put to himself the question how to measure chemical forces, for he considered, with Berthellot and other people of his time, that chemical action is due to gravitation or attraction between the atoms. His question, then, was as to the means he had at hand to measure and express in a quantitative way these chemical actions.

Finally, he invented the following process. Take, for instance, similar pieces of different materials, copper, zinc, bismuth and so

Digitized by Google

on, and cast them into similar shapes, for example, in the shape of cylinders of different cross-sections. Then cover these cylinders on all sides with wax, or some other impenetrable substance, so that only one cross-section of the cylinder can be seen, and put them in acid. The acid will then act on the metal by means of chemical affinity, or chemical force, and the larger the chemical force is, the greater will be the action. Then, of course, it occurred to Wenzel that one and the same acid, for example, nitric acid, would act differently on the same metal in different shapes, if diluted in different ways, and he now expressed his theory upon the cause of the influence of dilution upon the velocity of this chemical reaction. He expressed himself quite plainly, that if the acid was diluted to double the volume the action required double the time, therefore the velocity must be inversely proportional to the dilution.

This law that the velocity is proportional to concentration is indeed a fundamental law of chemical dynamics, and Wenzel is recognized as the first to expound this law.

But I have tried in vain to find in Wenzel's book some records of actual experiments in this line. He only gives his theory and explains the possibility of measuring chemical forces in this way by means of velocity in the introductory chapter of his book, but then drops the matter out altogether. There is no mention of this method or of any results obtained by this method later.

This is rather surprising because Wenzel even treated the case of mercury where the metal is liquid and could not be cast in the form of a cylinder, but which he placed in a glass tube, exposing the surface of the cross-section of the cylinder thus formed to the action of the acid.

The law of Wenzel's remained quite forgotten, nobody even mentioned it. Even in the history of chemistry I find no mentioning of this remark, and it was again brought to light only later.

The next mention we find is in the Statique Chimique of Berthellot, the same book we mentioned yesterday, but neither does he describe any experiments concerning these questions of the velocity of a chemical reaction, although he does give a kind of theory — not a theory exactly but an explanation — that the chemical action should be comparable to the conduction of heat. Just as a cooler body, when brought in contact with another, warmer one, causes an equalization of temperature, in the same way different chemical substances acting on another would equalize the chemical

Digitized by Google

forces, so that it is likely that the same laws which govern this conduction of heat should obtain with such chemical conditions or, as he expresses it, should cause chemical equilibrium. Bertholiet, again, was right, for a very simple type of chemical action, of chemical kinetics, follows the law of heat conduction.

But Berthellot lacked the experimental means to measure such reactions, although he developed a mathematical theory. Here again the correct law was found by a quite unknown German physicist. It is rather astonishing to have to mention again a German discoverer in this line who has remained unknown until the latest time, but of course I can not do anything else than record what I find. The facts are in the history of chemistry and the facts that these people have not been recognized is explained easily because the general course of chemical development was not recorded in Germany in the beginning of the first half of the last century, but in France, and French scientists did not care very much about foreigners, for to them generally the history of science begins with the first Frenchman who occupied himself with the particular question.

This man's name was Wilhelmy and he did no important work in any other part of the science. This was, in fact, his only child, but it was a big one. Wilhelmy was a physicist with some knowledge of chemistry and he was rich. He bought an apparatus for measuring the revolution of the plane of polarized light in rock crystals and liquids like turpentine oil or Schoenbein solution. Now it was known by former investigation that Schoenbein's solution changed its rotatory power if mixed with acids. It was inverted. The name "inverted" comes from the fact that while pure cane sugar rotates the plane of polarization to the right, chemical sugar which has been treated with diluted acids rotates it to the left, *i. e.*, the treatment inverts the direction of the rotation.

Now Wilhelmy observed the same fact. It was, indeed, not a new fact at all. It had been described already quite extensively and it was known that by this operation the cane sugar was transformed into two other kinds of sugar.

The important side of this fact was that it was a slow reaction, and by measuring the revolution of the plane of rotation it was possible to analyze the result of the reaction at every instant without disturbing the whole set of forces. For if any other means of determination, as ordinary chemical analysis, had been applied, the

Digitized by Google

whole equilibrium of sugar would have been disturbed and destroyed, and it would have been impossible to follow the progress of the change. But because this optical means allowed the inspection of the chemical state of the homogeneous system without interfering with the substance itself, it was possible to discover the laws of chemical kinetics, *i. e.*, the laws of slow chemical action, or the relation between chemical actions found in this peculiar case.

Wilhelmy observed the slow process, and then tried at once to find a mathematical expression for his observations. You will allow me to write on the blackboard a little differential equation, it will not be very difficult to understand and I will put it in the way given in Wilhelmy's paper.

If the quantity of sugar in the observed form is called Z then by dZ, as usual in calculus, we may designate a small quantity of sugar connected with some process. Now the sugar is constantly disappearing and the quantity of the sugar is measured by the rotation of the liquid. Therefore to designate the quantity of sugar disappearing in a short time, say a second, or a minute, as we may choose as a unit, we use this term dZ. dZ, then, is the quantity of sugar disappearing in the small time dt and, because it disappears, it is to be put in the negative sense. The relation between the sugar disappearing and the time in which the quantity of sugar disappears is the definition of a chemical velocity. Spatial velocity is the bit of space or length traversed in a certain time, and if expressed in terms of calculus, would give dl divided by dt (*i. e.*, dl/dt), *i. e.*, a linear velocity. In the same way we can describe other velocities.

Now this velocity of inversion of sugar will be proportional to the amount of sugar existing at the time in the solution, and in addition proportional to a constant depending upon the nature and quantity of the acid, though we do not express all these latter varieties. but include them in the constant we call k. Then the equation of Wilhelmy is that the velocity of the decomposition of the sugar is proportional to the concentration of the sugar existing at this moment in the sugar.

You are aware that the letter representing the quantity of sugar in the solution is a constantly changing quantity. As time goes on more and more sugar disappears and slower and slower will be the transformation of the rest of the sugar. If half disappear and react for the same amount of time, only half of the former quantity of sugar would be transformed. And, of course, the velocity must go

Digitized by Google

down because the constant is dependent upon the amount. This is the simple idea contained in Wilhelmy's differential equation, and experiment showed his equation to be perfectly correct. He could calculate the velocity of the reaction at any stage of the whole process, and showed that the formula is right for the constant term (k) was indeed quite constant, *i. e.*, it did not change during the whole process. This was the proof that Wilhelmy's assumption was right, that this differential equation assuming the velocity of the reaction to be proportional to the concentration of the acting body expressed indeed perfectly well the real state of affairs.

You recognize at once that it is just the same law which Wenzel had assumed without recording experiments to prove it. Therefore Wilhelmy's works confirmed the work of Wenzel and was the first experimental investigation of the general question of the velocity of chemical reaction. Wilhelmy did not overlook the importance of his discovery, and expressed at once his opinion that the law as found for sugar is not the peculiar law of this peculiar reaction, but rather a general law, applicable to any kind of chemical reaction or reactions of the same kind. Although Wilhelmy's work was published it remained entirely unnoticed. This is another work which I have had to dig out from oblivion and bring to the notice of my fellow chemists, and in later times Wilhelmy's merits have been recognized. Wilhelmy developed his theory only for the case that there is a single substance undergoing chemical change, and the question still remained, What will be the law of chemical kinetics when more than one substance is reacting upon another, or more than one substance is changing its concentration during the reaction?

The further development of this question was along a rather complicated way. The same names I had to mention yesterday as connected with the question of chemical equilibrium come again into the question of the development of chemical kinetics, viz., Harcourt and Esson, Guldberg and Waage, and Berthollet. Berthollet's work was first of all, but Berthollet's equations were incorrect while the equations of Harcourt and Esson, and Guldberg and Waage, published independently at the same time, were correct.

Harcourt and Essen have much more to do with the theory of chemical kinetics. They are not to be mentioned in the theory of chemical equilibrium. This is to correct a statement of yesterday.

Digitized by Google

Indeed, this work turned out to be a simple enlargement of these first equations of Wilhelmy. If there is more than one substance concerned in the chemical process, the velocity of the reactions is simply proportional to the concentration of every one of these different substances concerned in the process.

So if we designate the first of these substances concerned in the chemical action by 1, and by 2 another substance, and by 3 the third substance, the whole equation turns out in just this way, that there are as many factors as there are substances concerned in the chemical process, *i. e.*, as many factors come into the general equation as there are substances changing concentration simultaneously. One substance can never change if the other does not change. For example, if there is an acid being saturated by a base, at the very same moment equivalent quantities of the acid and base must disappear, and it will not matter whether we measure the acid or the base. Therefore only one quantity has to be measured. This is the general law of chemical kinetics as long as one reaction is concerned. But there are other cases where one substance acts on another, and the product of the reaction can react back again to form the base substance, as by the inversion of sugar. Water is taken up and the sugar divided into two components, but under certain circumstances the two components unite and form sugar again, so the process can be reversed, and this is quite general, for, as you know, chemical processes rarely lead to a unique result, but to a chemical equilibrium.

We will repeat our equation of yesterday again and see what is to be told from the standpoint of chemical kinetics by this equation. You remember that we had a relation then by which we can express every possible chemical reaction in the terms of the reacting substances, and have as many members as there are substances acting upon some other substance. Now the meaning of this equation is that the chemical velocity, as expressed by dZ/dt or V_a, at this stage of the reaction is expressed by a constant multiplied by the concentrations of the substances, each raised to the power m or n_1, etc., equal to the number of molecules reacting. And the reverse reactions, the velocity of which we shall call V_b, will be expressed by a similar equation, and the actual velocity — that is the velocity in one sense — is

$$V_a - V_b = k_a a_1^{m_1} a_2^{m_2} - k_b b_1^{n_1} b_2^{n_2}.$$

Digitized by Google

This is a general expression, $V_a - V_b$, which we may call V, the mathematical expression of the resulting velocity of such a process, *i. e.*,

$$V = V_a - V_b = k_a a_1^{m_1} a_2^{m_2} - k_b b_1^{n_1} b_2^{n_2}.$$

It looks rather difficult, but you will see at once that it concludes itself to a very nice result. It means equilibrium. Equilibrium means that nothing will change in time. This is our general definition. Nothing will change in time then in our reaction if the change from one side to the other is the same as that in the reverse direction. In other words if V_a is equal to V_b (*i. e.*, $V = 0$), equilibrium will exist. You will recognize that the equation of equilibrium we got yesterday from the theory of chemical equilibrium, as expounded by Guldberg and Waage, leads here to the same results as the general considerations of Wilhelmy, both agreeing that the velocity of a chemical reaction is directly proportional to the concentration of the reacting bodies.

This is not all there is to tell about the chemical kinetics, but it shows the close connection between these great divisions of general chemistry and I would like only to point out a few other facts: some more relations which show the importance of the knowledge of chemical kinetics in the study of the velocity of chemical reactions.

If we investigate, for example, the general construction of our body, or of the body of any living organism, plant or animal, we can describe the main features of these existences by making a study of the chemical change going on in time. These go rather slowly mostly, and are related one to the other in such a way that equilibrium is reached. It means, for example, that the reaction between the oxygen of the air we are breathing and the carbon of the nourishing substances we take into our bodies, which is burning, is quite well regulated. We have for this regulation the constant temperature of the body, and the necessary amount of other kinds of energy for maintaining the different activities of the body, for a slight acceleration of this oxidizing process goes on whenever the temperature is raised. We feel uncomfortable, if only a few degrees too much heat are developed in the body, for then the body can not exist any longer, it perishes from irregular chemical reaction. Now, if you will look closer into this time of chemical reactions, you will observe a very curious and unexpected kind of reaction. For example, if you lay on the table a piece of sugar or of meat or bread, you will see that they are in contact

Digitized by Google

with the atmosphere, or with the oxygen, and will probably ask at once why they don't burn, for when we have eaten these materials and bring them to the temperature of the body, a little higher than the temperature of the room, it causes these materials to burn. Neither bread nor butter nor any other of the constituents of our breakfast will burn at the temperature of our body, and nevertheless our body burns these materials with slight changes just at the requisite rate to maintain the temperature of the body; and the process keeps the temperature of the body constant in an astonishing way. Our bodies are really thermostats of surprising perfection. It took a long development in chemical technique to construct thermostats regulating with the same perfection as our bodies. To make it perfect and secure even regulation of the combustion of our food material inside the body, the body must possess several means of regulating the velocity of combustion, for the required amount of heat must be developed to suit the various conditions it meets; for example, in the room or in the open air. Therefore you will see at once that the proper regulation of heat by chemical velocity is only one instance of its importance, for all the other functions of the body depend upon chemical energy. Even thinking is dependent on the chemical change, and, here again, the rate of chemical energy attained is of the utmost importance for every function of the body, therefore the property of the regulation of chemical kinetics in the body is just the condition for its existence. The moment this regulation is disturbed there is danger of immediate death.

Many persons are working in such a way that they change the rate of the oxidation or some other process in the body, and in this way disturb the dynamic equilibrium of the body.

Now we must turn to the question as to the means by which this chemical velocity may be regulated, and what means we would expect to find in the organisms for the purpose of this regulation. The most general factor is the temperature. Chemical changes are largely influenced by changes in temperature almost without exception. Only one or two cases have been found in the oldest times of such exception. Almost in every case the rate of chemical change is largely increased by a rise of temperature and there are very few functions indeed in the whole physics of chemistry which are influenced to such a degree by change of temperature as chemical velocities are. The velocity of most chemical reactions

Digitized by Google

is doubled by a change of temperature of about 10° C. This is an enormous change, so that even a small change in the temperature will cause considerable disturbance in the processes of the organisms depending upon the mutual regulation of the different reactions.

So much for the influence of temperature. Then there is of course the influence of the nature of the substances which are in contact. There have been no general laws discovered as yet which would express these relations. I will only say that although there are some laws known, I will not mention them because they are not yet arranged, and are not of great importance.

Then there is still another very curious circumstance. There are chemical reactions which are going on under normal circumstances at a very small velocity, taking days and weeks to be performed; in several cases even months and years. And then there are certain substances which act in such a way, that if you put them into the field of reaction, you can find the substances every moment, and yet the reaction goes on much quicker than before. It appears then in many cases as if the addition of these different substances, which we can extract *unchanged* at any time from the system, causes the reaction to be started. The discovery of such facts is rather old. It goes back again to a German who made the first observations; his name is Kirchoff, a pharmacist. He observed and pointed out the first fact in this line that by treating starch with dilute sulphuric acid, the starch turned into sugar. It was a very important thing at that time because of trade relations. Sugar was obtained then only from tropical parts, to make sugar at home from the products obtained from the regular crops was consequently a great feat and people were much astonished by it. The fact was investigated from all sides. Kirchoff himself did the first part of this investigation. He found that starch changes directly into sugar. The quantity of sulphuric acid employed does not change at all, and does not enter the sugar in any way. This mysterious action was recorded and nothing more was said about it. Then quite a number of other, similar processes were discovered, and always again this mysterious action of a substance, which did not disappear or change at all during the process, yet without whose help the process would not go on, or would go on so slowly that nothing could be done, was observed.

This unsatisfactory state of affairs lasted until about the middle of the nineteenth century when Berzelius, with his admirable power of

Digitized by Google

finding similarities between puzzling facts, and pointing out the important sides of these facts, turned his attention to these reactions and established their existence in science just in the same way as I explained to you some days ago; he simply recognized the new concept, and designated it by a name. Berzelius explained in the terms of his theory, his electrical theory of chemical action, that certain reactions were brought about by the presence of substances which did not disappear during the reaction, and which could be recovered after the reaction in just the quantity in which they had been introduced into the reaction; but without whose help the reaction would not go on. He named this peculiar kind of action catalytic action, and the peculiar substance the catalyzer, and then put off the entire question for later investigation. It was a quite sound way to take up the question, but the right way was defeated by a man named Liebig. Liebig was at this time rather dissatisfied with Berzelius's views. Berzelius was rather an old man and the new development of organic chemistry with which Liebig was connected went on some opposite lines to Berzelius's ideas, and so Liebig felt rather unfriendly toward any idea of Berzelius. He just adopted his idea of catalysis and accepted it not as a name, but as an explanation. Berzelius had intended no explanation, but only a name for a new concept, for science did not know enough to attempt an explanation upon such slight grounds, and so run the danger of spoiling a later investigation by preconceived ideas. This did not please Liebig so that he gave a preconceived idea; and this idea has remained indeed as a stumbling block for the later development of the science of catalysis until our days, *i. e.*, about ten years ago. Liebig explained this thing as not strange at all. I will suppose that this action on sugar is another case of catalytic action similar to the change of sugar into alcohol and carbonic acid, and starch into the sugar; or to come back to Wilhelmy, as you change sugar into the mixture of lævuiose and dextrose. Now Liebig considered every complex chemical substance which is in a state of decomposition, the organized nature of which was not recognized at that time, as one in which the atoms are moving very energetically to and fro. His idea, then, was that the moving atoms of sugar get shocks and break asunder, so that it is but to be expected that they might form alcohol and carbonic acid. And in the same way catalysis is a substance undergoing change and breaking up in the same mechanical way, separating the atoms of the substance acted upon.

Digitized by Google

It is, of course, impossible to assume that there is any violent motion in very stable substances. Hydrochloric acid, for example, does not change, and yet nevertheless it acts powerfully as a catalyzer. But it is true that these ideas of Liebig, so little proven and so little sensible indeed as they were, remained in the foreground during the whole time until about the 90's of the last century. You will find from time to time that a chemist has used the term catalyze, and another chemist has found himself obliged to point out that it is not an explanation, but only a name. Indeed it was not possible to explain these reactions on the basis of the old chemical knowledge. Only after the theory of chemical kinetics was developed did it become possible to give the scientific definition to catalysis. A catalyzer, in such a sense, is a substance which changes the ratio of any change by its presence. How it does, remains untold, *i. e.*, remains as a subject for further scientific investigation, but a general view is that no catalyzer can bring about a chemical reaction which could not go on by itself. It would be against the laws of energy, into which I can not go, but it cannot be done. Only chemical reactions which are possible by themselves can be accelerated by the presence of any substance. The process may be slow, but it is none the less taking place, if it can be acted upon by a catalyzer. Just the same answer applies to the question as to why the coal in the cellar, or the bread on the table does not burn. They are burning, but the process is going on so slowly that it is not noticeable. There is always carbonic acid in the air of your coal cellar, more than in the outside air, just because of the quantity of coal which is burning very slowly. There are instances known where fresh coal in the pit has got burning so rapidly that it has heated itself and burst into flames and burned at a high and noticeable rate.

Every possible chemical reaction in a homogeneous system is going on thus continuously, but very often at such a slow rate that we cannot observe it, or only observe it with great trouble, or with very refined means. Such reactions, which of themselves are progressing very slowly, may be accelerated by the presence of certain substances, and such substances which accelerate slow reactions we call catalyzers. And now that theory leads to enormous investigations. We can ask what substances act as catalyzers for these reactions, but will the law for the actions of the several substances be the law for the action when more than one of these catalyzers are acting

Digitized by Google

simultaneously? At once we open the field for quantitative chemical results simply by observing that catalytic action can only go on in chemical processes by the presence of some substance.

How such substances accelerate these chemical processes is still an open question, but in the latest times we have obtained the first experimental confirmation of an idea about a hundred years old, which has been read and often quoted during this time, but which has never received quantitative investigation and proof.

This idea was first developed by Clement and Dèsormès in regard to the sulphuric acid process. You know in sulphuric acid there is water, oxygen and sulphur, and the question is — why don't these combine at once to sulphuric acid when all the necessary substances are present? But they do not and we know that if only these substances are present in the chamber we get a very poor output of sulphuric acid, but that when we add some other substance, nitric acid, the process goes on with great velocity, and turns into a practical, and, I think you will agree with me, a most important chemical process.

Now, to explain the way of action of these oxides of nitrogen, Clement and Dèsormès in a classical work explained that it may happen in such a way that sulphurous acid is not oxidized by the free acid, but by the peroxide of nitrogen; and that these oxides act as carriers, catching the oxygen and bringing it to the sulphuric acid, for the sulphuric acid can take it from the nitrogen peroxide, but cannot take it when free. There is something difficult to understand and something seemingly contradictory in this idea. One should expect that sulphurous acid could take free oxygen easier than combined oxygen, but it goes inversely. Combined oxygen goes much quicker to sulphurous acid than free.

Measurements of this have been made and investigated, but the process is such that actual measurements were impossible.

Then another case was investigated. A suggestion of Professor Luther, it was just to make matters possible. It is a fact that persulphuric acid will not oxidize phosphorous acid, for the solution will remain unchanged for weeks together. But on the one side phosphorous acid will reduce free iodine to hydriodic acid, and on the other side, hydriodic acid will be readily oxidized by persulphuric acid. Therefore we have the case named, with A, B and C. A will not act on C; A means sulphuric acid and C means phosphorous acid; but A acts quickly on B, and B acts quickly on C.

Digitized by Google

Therefore if we bring together *A* and *C* there is no action, while if you bring in *B*, which has nothing to do with oxidation of *C*, oxidation will go on just because *A* oxidizes *B* first, and *B* then oxidizes *C*. All these three reaction velocities can be and have been measured. They were measured by a rather complicated process, but the results showed that the substance hydriodic acid is a carrier for the oxygen from the persulphuric acid to the phosphorous acid. This is, so far as I know, the sole case where such numerical investigations have been carried out, but it proves that there are a certain number of these actions which take place by the means of intermediate action. Possibly all cases cannot be explained in this way, but just to show that it is indeed possible to handle the whole question in the scientific quantitative way, I have entered into these discussions.

Now, I wish finally to point out the great importance of catalytic actions everywhere where chemical reactions are going on. All possible brewing and baking, and digesting, are directly dependent on catalytic action. Baking depends on the action of changes of the starch and sugar, and all of these processes are catalytic in nature. In the same way brewing depends on the action of the catalyzer. It is also the same with our digestive apparatus from the mouth on, there are constantly such catalyzers in action.

Then in large chemical industries catalyzers are necessary. The sulphuric acid industry depends entirely on catalytic action.

Just now there is developing another process of sulphuric acid by means of platinum, which is again a catalytic action. And so a great change in the appearance of artificial indigo is again due to the accidental action of a catalyzer. Artificial indigo is made from naphthalene and sulphuric acid. Now in the laboratory of the factory this process was investigated and it was found that the action goes on very slowly indeed, so that its useful application seemed impossible. Then suddenly it was observed that this oxidation went on very quickly and quite regularly, but this case looked rather unclean, for the thermometer was broken and the experiment was in a little disorder. Finally the experiment was repeated again but the process was poor again, and at last it was discovered that the broken thermometer had had something to do with it, and they knew at once that the mercury was the catalyzer for this naphthalene. And so this important process also depends upon a catalyzer.

Digitized by Google

Until now these all-important means for technical chemistry have been applied only by accident, because science has not developed as yet a general theory for catalyzers. But now catalysis is no longer a word to be laughed at, but a scientific fact, a chapter of science of great importance. Its development has been so rapid that now we may expect that the application of catalytic processes in large industries will increase every day. The reason for this may be stated in a few words. By a catalyzer you increase your process. You bring the same thing out, but in a much shorter time, and without any expense but for the catalyzer, and that may be used over and over again.

And now, as I am going to conclude these lectures, I cannot do so without following our German custom, that is to thank you all for the patience and the kind interest you have shown in hearing what I have had to say.

Digitized by Google

THE APPLICATION OF METALLOGRAPHY TO OPAQUE MINERALS.

By WILLIAM CAMPBELL.

Table of Contents.

	Page.
Introduction	414
Preparation of Samples	415
Grinding and Polishing	415
Development of Structure	416
Microscope and Accessories	417
Illumination	418
Photography	418
Examples of Use of Method	419

In a previous paper * the methods used for the metallographic examination of metals and alloys have been set forth. For the past two or three years these methods have been so successfully applied to the examination of opaque minerals, that the publication of certain details of procedure may prove of value to others interested in the work.

Metallography is the description of the structure of metals and alloys, usually from their polished surfaces, using reflected light. The microscopic examination of polished surfaces of opaque minerals by reflected light, we might therefore call minerallography.

The work divides itself naturally into two groups: *A*, the examination of single minerals; *B*, the examination of ore bodies.

Under the first heading falls the work of determining the microstructure, the constitution, the inclusions of other substances, the method of decomposition, etc. By this line of work we can answer such questions as "By what stages does chalcopyrite become limonite and malachite?"; "Does nickel replace iron isomorphously in nickeliferous pyrrhotite?"; "In what state does the silver occur in argentiferous galena, blende, tetrahedrite, etc.?" "Do minerals with complex formulæ owe this complexity to a mechanical mixture or not?" Under the second heading comes the work upon the genesis of ore bodies, whereby we can find the relative ages of the various constituents and of any dynamic or chemical changes which have taken place. In other words, we do with

* "Notes on Metallography," School of Mines Quarterly, No. 4, Vol. XXV., p. 390.

Digitized by Google

opaque minerals what petrology does with thin sections of the transparent ones.

Preparation of Samples.

The size of the sample can vary within certain limits set by the type of microscope used. For convenience it is best to make it as near one inch square and one half inch thick as possible. If the whole of the structure to be examined cannot be embraced in this size, it is easier to polish two pieces than to work with one double the size.

A chip one half inch thick can usually be broken off the hand specimen with a hammer and is easily trimmed down to about one inch square. In the examination of single minerals individual crystals make good specimens. It sometimes happens that the material to be examined is very brittle and tends to disintegrate during the process of polishing. In this case it is necessary to supply a firm background or support. Certain waxes, resins and cements can be used but they must not be softened by the slight heat produced during the process of polishing. On the other hand, the specimen may not be brittle enough to break with a blow of the hammer, as for example, in the case of native metals. A small saw may then be used to advantage.

An important point to be remembered is that we can strain minerals and native metals just as we strain metals and alloys: that where this strain is severe the final structure will be more or less modified by it. This is clearly brought out in the examination of native bismuth, copper, etc. In the process of extraction the specimens are usually more or less strained. Under the microscope the finished specimen shows up these strains as slip-lines, slip-bands or twinning. In the case of minerals, however, the effects of this kind of strain are comparatively slight and when we do find slip-bands and the like, as for example in galena, magnetite, pyrrhotite, etc., these are due to great strains and movements in the ore-body itself.

Grinding and Polishing.

As in the case of metals and alloys, the main object is to obtain a perfectly flat surface. If a lap-wheel is on hand, a surface can easily be ground down as in making rock-sections. However, an emery-wheel or even a grindstone may be used for the purpose.

Digitized by Google

The second part of the process consists in rubbing the specimen on a sheet of ground plate glass, covered with emery powder (No. 100) and well moistened with water. It was found that carborundum powder gave quicker results than emery. From this point the treatment varies according to the nature of the specimen, for it is found that the most rapid method for one kind of material was often the slowest for another.

For very hard substances like pyrites, it is best to continue the treatment on the ground-glass plate using carborundum powder No. 3F and "flour." After this the specimen is rubbed on French emery paper and is then ready for the rouge.

For softer substances like galena, it is best to take the specimen down on No. 00 emery paper which is followed by four grades of French emery paper Nos. 0 to 0000 (Hubert) after which it is ready for the rouge. In taking the specimen through the various grades of emery paper, the direction of rubbing is turned through 90° when we pass from one paper to the next and the rubbing continued until all the scratches of the previous paper have disappeared. In the case of very soft material care must be taken not to strain or distort the surface in the process of grinding and polishing. In some cases this can only be done by using a very fine-grained water-of-Ayr stone with water. The success of the work up to this stage and in the next is largely due to the grinding and polishing medium. If material free from grit cannot be purchased, one is compelled to wash it thoroughly.

The final polish is obtained by rubbing on broadcloth covered with well-washed rouge and water which is conveniently kept in a wash-bottle.

As long as care is taken, it is the same whether we use a wooden block or a polishing machine. The latter greatly reduces the labor involved but requires more care to guard against pitting of the surface of the specimen and extreme polishing-in-relief. As soon as the last scratches disappear, the polishing is finished, as it is usually a waste of time to try and work out any except those from the last French emery paper.

Development of Structure.

Having obtained a more or less perfectly polished surface, it may or may not be necessary to apply further treatment to develop structure or to distinguish between two or more constituents. It

Digitized by Google

is always a good plan to examine the specimen carefully after polishing, because quite a lot of information can be gathered from color, hardness, habit, etc. Then having distinguished the various constituents as far as possible, we can proceed to examine its behavior under various reagents. The preliminary work in this direction can be done under the microscope, and the process of attack carefully followed.

Using 1.4 HNO_3 the following solutions can be made up: 10 per cent., 33 per cent., 66 per cent. in water. Similar solutions can be made from HCl. We note the color after etching, depth of etching, any structure developed and variations in etching. The reagents can also be tried hot. In the event of these reagents proving unsatisfactory, others can be tried, such as the chlorides of copper, tin or iron.

The use of the electric current in etching has many advantages amongst which is the control of the etching by regulating the intensity of the current. By placing the etching bath in series with a 4 c.p. lamp on the 110-volt circuit very good results were obtained with certain copper minerals.

After etching, the specimen is thoroughly washed under the tap, soaked in alcohol and dried by pressing it upon a dry soft rag. It must not be rubbed in drying, although there is often a deposit formed during etching which may be removed by gently rubbing with the ball of the finger whilst under the tap.

Microscopes and Accessories.

The ordinary petrographical microscope with a fair working distance between the objective and the stage is all that is required. As reflected light must be used, we need reflectors. When working with a one-inch objective the Sorby-Beck reflector is used and we can obtain both vertical and oblique illumination. With objectives of higher than one inch, the Beck illuminator, or Nachet or Zeiss prisms can be used.

In the case of anyone purchasing a microscope solely for metallographic work, three instruments should be considered. The first is that of the Boston Testing Laboratories, manufactured by Bausch and Lomb. The main advantage possessed by this microscope is the raising and lowering of the stage by rack and pinion motion. Having once adjusted the illuminating apparatus, lamp, condensers, etc., so that the beam of light is centered on the aperture of the

Digitized by Google

vertical illuminator, their position need not be altered, for all adjustments for change of specimens or objectives are made by the motion of the stage. The microscope is usually used in the vertical position.

The second microscope is the Martens' stand, manufactured by Zeiss, and is made to use in the horizontal position. Although the tube is provided with a coarse adjustment by rack and pinion, this is only used for transmitted light. Like the first instrument, focussing, etc., are performed by a rack and pinion attachment to the stage which also carries a micrometer screw for fine adjustment. As before the optical bench attachments are set up and adjusted once for all, all subsequent movement taking place in the stage and not in the tube of the microscope.

The third microscope designed by Le Chatelier and manfactured by Pellin, Paris, embraces in its latest form many advantages. The stage has now been fitted with a rack and pinion adjustment for focussing. The lower prism being fixed on a pivot the beam of light can be reflected along the eyepiece tube, now at 90° to the illuminating tube. The camera is now fixed in line with the illuminating tube in the horizontal plane and by turning the lower prism through 90° light is reflected into the camera. In other words, the camera takes the place of the eyepiece tube in the old form.

Illumination and Photography.

For all ordinary work up to 500 diameters the incandescent Welsbach gas burners answer best. For higher power work an arc light becomes necessary. (For photography the arc light becomes almost necessary above about 200 diameters.)

The electric arc lamp illuminating apparatus manufactured by Bausch and Lomb is excellent in every way. The lamp has a 90° arc with adjustments in three planes and works exceedingly well. To the outfit the Boston testing laboratories have added certain improvements amongst which may be mentioned an automatic shutter.

For any microscope working in the vertical position, the best camera is probably that manufactured by Bausch and Lomb, which takes plates up to 4 x 5 inches. It owes its rigidity to its heavy iron base and steel supports. For microscopes working in the horizontal plane the Zeiss camera will be found very convenient and easy to manipulate. Pellin manufactures cameras for use with the

Digitized by Google

Le Chatelier microscope, the whole outfit for which includes an optical bench with Nernst lamp, cells, etc.

For low power work Eastman and other brands of ordinary plates give sharp definition and enough contrast. With a magnification of say 80 diameters, vertical illumination with Welsbach, of materials like a mixture of pyrite and bornite, an exposure of 30 seconds will be sufficient. For higher power work, orthochromatic plates and a color-screen are necessary. Using an arc light, Forbes orthochromatic plate (fast) and yellow screen, a magnification of 250 diameters required four seconds exposure.

Examples of Use of Method.

1. *Examination of a Specimen of Decomposing Chalcopyrite.*— Fig. 1 magnified 80 diameters shows the structure of chalcopyrite in the process of decomposition. The bright light-colored central material is unaltered chalcopyrite, whilst the darker network is made up of the decomposition products. On etching with a solution of one nitric acid (1.4) to three of water this network is seen to be complex. Fig. 2 shows another view of the same specimen after etching. The chalcopyrite is unattacked, but now shows up a system of cracks, whilst around it as an envelope lies a deep-etching material which proved to be chalcocite. Beyond this, forming the rest of the veins, lies the iron oxides, etc. Lastly in the center of some of the broadest bands of decomposition we have thin veins filled with malachite. The resemblance to "Kernel-Roasting" is strong. The photographs only give an imperfect idea of the structures, which have to be viewed by both oblique and vertical light to show up at their best. By examining different parts of the specimen the process of decomposition can be followed from fresh chalcopyrite to limonite and malachite. I have to thank Mr. Kellogg for this and other specimens from the Cochise Mining District, Arizona.

2. *Genesis of the Constituents of an Ore.*—Fig. 3 magnified 80 diameters shows a specimen from Butte. The hard rough material standing in relief is pyrite, whilst the interstitial spaces are filled with a mixture of bornite and chalcocite. Even without etching the bornite is easily distinguished from the chalcocite by its pinkish tinge, and etching with dilute acid makes the difference more marked for the chalcocite then shows up a structure peculiar to itself. Fig. 4 magnified 80 diameters shows a large

Digitized by Google

FIG. 1.

FIG. 2.

Digitized by Google

FIG. 3.

FIG. 4.

Digitized by Google

area of the two after etching. The upper part of the photograph consists of chalcocite, which is composed of grains each with its own orientation, while the lower part is bornite with its peculiar decomposition cracks. The pyrite was the first mineral to form and was afterwards fractured and eroded and then around it the bornite was deposited. The last to form was chalcocite, which is seen to cut the bornite in veinlets and stringers.

A recent paper on the "Paragenesis of the Cobalt-Nickel Arsenides and Silver Deposits of Temiskaming" * works out the order of deposition by metallographic means. First of all came the smaltite, then the niccolite. These were fractured, after which followed the deposition of calcite. Next came argentite, and lastly native silver.

The above examples are given merely to illustrate the results obtained in this method of work, which ought to find a wide application, especially in those cases where the order of formation cannot be distinguished with certainty in the hand specimen.

In conclusion I have to express my indebtedness to the Carnegie Institution of Washington whose grant for apparatus made it possible for work to be done along this line.

* Campbell and Knight, *Eng. and Min. Jour.*, June 9, 1906.

Digitized by Google

STRESSES IN THE COUNTRY ROCK AS THE CAUSE OF AIR BLASTS IN THE MINES AT PRIBRAM, BOHEMIA.*

By HUGO STEFAN,
General Manager.

In many coal mines air blasts are a phenomenon of not uncommon occurrence and more exact knowledge as to their geological relations is desirable in order to secure greater safety in the working conditions underground. They are by no means confined to collieries, however, and have long been known in metalliferous mines as well. Their nature and mode of occurrence can only be fully elucidated by correlating as many observations as possible from various places and persons.

Dynamic Processes.

Stresses in the country rock may develop from chemical as well as from mechanical causes, although in the case under discussion the latter alone are of importance.

Assuming that there be at any point in the earth's crust a strain such as would tend to buckle the rocks in which it occurs, it will vary in its effects according to the physical characteristics of the different strata; thus, mild and plastic clays will behave very differently under tension than harder and more brittle coal. Conditions prevailing near the surface, moreover, are quite different from those at great depths. If the buckling force is brougth to bear on a rock stratum at great depth, the direction of the movement taking place in the folding of such a layer will be opposite to that in which the force of gravity acts on the rock. Near the surface of the earth equilibrium of these stresses has long since been established, partly because the original superincumbent strata have been removed by denudation or else because deep weathering or disintegration has loosened the ground and so allowed it to yield readily. As long as any bed in a formation maintains its solid relationship to others, it is in a position to withstand much

*Translated for the *School of Mines Quarterly* by C. R. Corning from *Oesterreichische Zeitschrift*, 1906, p. 256.

Digitized by Google

greater forces than after having been disturbed or loosened. These conditions, which are so frequently found in mines, are similar to those prevailing in a rod or column under longitudinal compression. Such a rod, fixed only at its two ends, will be bent in proportion to a force:

$$K = \left(\frac{\pi^2 ET}{L^2}\right)$$

in which formula

K = the force,
ET = moment of flexure,
L = length of rod.

If it be firmly fixed at 1, 2 or 3 equidistant points along its length, 4, 9 or 16 times the above force will be necessary to produce the same result.

When the equilibrium of layers of rock is disturbed by underground workings and sudden changes of strain produced, breaks may occur with irresistable force, frequently resulting in the phenomena termed "air blasts." In support of this statement the following paragraph may be cited from F. R. von Hauer: Geology of the Austro-Hungarian Monarchy.

"Interesting observations on what may be termed a latent pressure to which beds of rock in their natural position in the earth's crust are sometimes subjected, and concerning the sudden breaking apart of such beds, have been published by Professor Niles of Boston. He noticed in a number of quarries in the United States that on loosening large sheets of rock from their original position, they underwent considerable expansion. . Actual measurements showed an increase in length of at least one in a thousand. It appears that this expansion occurred in a north and south, not in an east and west direction. In a limestone quarry at Lamont, twenty miles south of Chicago, on stripping off the surface, an underlying stratum of rock was exposed, which afterward buckled slightly, forming a wave-shaped crest or anticlinal, the ridge of which extended east and west for over 800 feet. The height of the anticlinal was 6 to 8 inches and its width about 18 feet. Later on a longitudinal fissure formed with a loud explosion along the crest of this fold. The buckling was evidently the result of a horizontal pressure, in a north and south direction, to which the strata yielded as soon as their over-burden had been removed."

Digitized by Google

Aside from chemical processes, therefore, the cause of air blasts may be assumed to be mainly a combination, in varying proportion, of several factors: (1) The composition, structure and cohesion of the rocky strata. These present varying resistance to pressure, together with conditions permitting the equalizing of internal strains. (2) Depth below the surface. Here the weight of the over-burden of rock tends to prevent the stress from being relieved by buckling. (3) The advance of surface weathering, if very extensive, produces elasticity in the over-burden, which is then easily forced aside or upwards by any tendency on the part of underlying formations to form anticlines.

Local Geology.

At Pribram a number of silver and lead veins are worked. They are frequently associated with greenstone and diabase dikes of various widths and have many stringers. These veins dip from 70° to 90° east or west, and run approximately north and south in a syncline of Cambrian sandstone from 2 to 3¼ kilometers in width. The northwesterly slope of this syncline dips 80°, while the southwesterly side is quite flat. The Maria shaft is 350 meters west of the bottom of the syncline. At a depth of 1,009 meters (the thirtieth level) the shaft is within 40 meters of this syncline and cuts it at the thirty-second level at a depth of 1,109 meters, where a vertical fault fissure traverses the horizontal strata so that east of this fissure the beds are 25 centimeters below their position on the western side. The course of the fault fissure is nearly at right angles to the sandstone strata. In the easterly and lower strata there are a number of calcite stringers up to 1 centimeter in thickness, traversing the strata and starting from, but younger than, the fault fissure itself. The individual beds, which often pinch out, vary greatly in thickness as well as in structure and composition. Very hard silicious grey-wackes alternate with clays, both fine- and coarse-grained, in dense more or less schistose layers.

The diabases, which are an important element in the structure of the formation, have, when fresh, much of the hardness of feldspar; when much altered, they are very soft. It is quite evident that the squeezing of the rocks incidental to the intrusion of the greenstones in the grey-wackes was the cause of much stressing.

The metalliferous veins which occur in the diabase and some-

Digitized by Google

times also in the sandstone, are accompanied by fissures of calcite, and these again by barren fissures showing many slickensides. All of this indicates that considerable movement has taken place. Although the average strike of the fissures themselves is fairly constant, they are in individual cases very crooked and much split up. It is noteworthy that the number of metalliferous veins is much smaller than that of greenstone dikes.

The realization to which these facts lead of the enormous forces which have come into play in this district is greatly strengthened by a study of the so-called Lettenkluft. This fissure cuts off the sandstone syncline to the northwest and is one of the largest fault fissures ever yet opened up by mining operations. It dips 70° to the northwest and adjacent to it are dark, much distorted and compressed slates. The fissure is older than the greenstone, but the mineral veins of the district, even if they do pass through into the slates, very soon become barren and at the same time are deflected to the northeast.

Such relations between stratification, country rock and metalliferous fissures give the entire complex an unusually varied character, so that the various forces to which it has been subjected have produced unequal stresses in its heterogeneous members. This condition of unequal stressing is to be considered one of the causes of air blasts.

Phenomena of Air Blasts.

At the Maria shaft there are two distinct conditions producing air blasts:

1. On driving drifts and cross-cuts in the hard greenstone, a crackling sound is frequently noticed. This is attributable to the formation of small fissures and is a warning to the miner, because angular fragments of rock are often thrown off with loud explosions from the face of the drift. Fortunately, these pieces are rarely large, but they are sometimes of sufficient size to cause painful wounds. The cause is probably to be sought in the pressure which the hanging and foot-walls exert in many places on the dike or vein formation. In most cases this pressure is produced at points where the vein changes its strike or dip (Fig. 1). A movement of the hanging or of the foot wall, or of both simultaneously, may then readily bring about a compression of the vein matter. Such movements, as well as irregularity of the fissuring, are

Digitized by Google

common characteristics of the Pribram veins. In cases where the walls are under pressure and converge, so that the vein filling takes the shape of a wedge, large and heavy blocks of ground may quite readily break loose (Fig. 2).

On abandoning work in ground subject to air blasts, the phenomenon as a rule rapidly quiets down, but promptly begins again when work is resumed. In spite of the use of the best methods of stope-filling known, the conditions in this mine are gradually

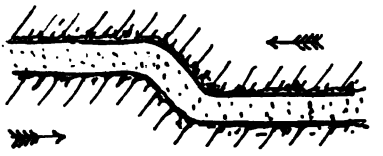


FIG. 1.

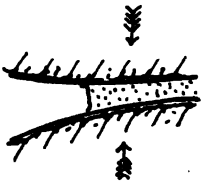


FIG. 2.

growing worse, as the stopes extend and as the pressure of the hanging-wall is concentrated on continually dwindling pillars of rock, but even under these conditions, air blasts occur only in hard vein matter or country rock. When the ground is soft or gougy, considerable falls of rock are apt to take place, but these must not be confounded with the sudden and unexpected air blasts.

2. A much more dangerous situation is produced by another type of air blast, which occurred for the first time at Pribram in 1897, when the thirty-second level south (1,109 meters) on the main fissure of the Adalberti vein was driven. This mishap cost the life of one of the men. On July 7 of that year the face of the drift was 37 meters south of the Maria shaft east cross-cut, at *K* (Fig. 4). The drift was 2.2 meters high by 1.5 meters wide, and on the hanging-wall side was in a greenstone dike, which had gradually pinched as the drift advanced. On the foot wall the face was in hard quartzitic sandstone, plainly stratified and with a flat dip (Fig. 3). Just after the two miners on shift had thrown back the broken rock and were preparing to drill, a piece of rock, weighing nearly 200 lbs., broke loose from the foot-wall side of the drift near the roof, exploding at the same

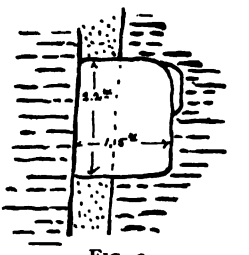


FIG. 3.

Digitized by Google

time into a number of angular pieces of various sizes with a detonation like that of a blast. Some of the pieces struck one of the men, crushing his skull and causing other serious wounds and bruises. Since then work in this portion of the mine, both on thirty-first level (1,059 meters) and on the thirty-second level (1,109 meters) has been uninterruptedly continued, the stope at present reaching 15 to 30 meters above the level. Layers of explosive sandstone have been encountered frequently on both walls of the drifts, but fortunately there have been no further casualties, on account of the precautions mentioned below. Sandstone often occurs in the levels and stopes, but as yet no explosive strata have been found above the depth of 1,000 meters and then always in the neighborhood of the intersection be-

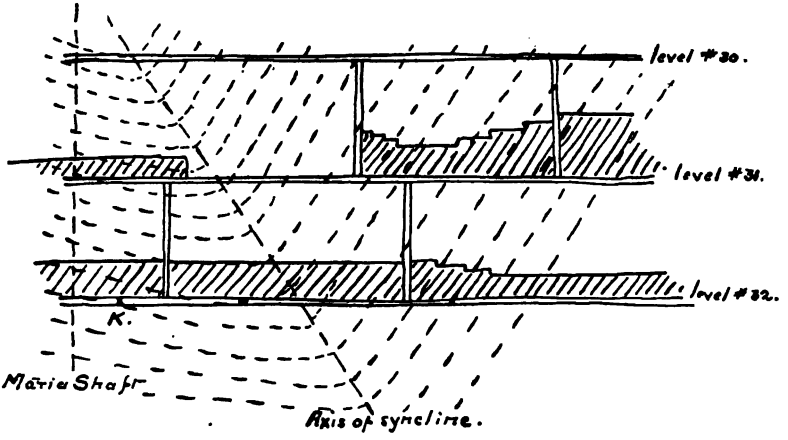


FIG. 4.

tween the trough of the syncline and the Adalberti fissure, and in the flat southeasterly slope of the syncline. Such air blasts as the above have never yet been encountered in the numerous workings of the southerly, steeper slope of the syncline. The pieces of rock which are thrown off with the explosion, bursting into numerous smooth-faced angular pieces, average as a rule half a cubic meter in size. Frequently, a heavy air blast at a particular place is followed at irregular intervals by a series of minor blasts, so that the stope cannot be approached with safety for hours, sometimes even for days. The various beds of graywackes are not all equally dangerous. It is rather the hard, fine-grained silicious layers

Digitized by Google

No.	Date.	Level. No.	Level. Depth. Meters.	Elevation Above the Level. Meters.	Distance From Main Shaft. Meters.	Distance From Axis of Syncline. Meters.	Vein Rock.	Country Rock.	Dip of Vein	Thickness of Vein. Meters.	Vein Filling.	Remarks.	Location of the Ground Under Pressure.	Results of the Air Blast.
1	24 Oct. 1905.	32	1,109	22	45 North	70	Diabase.	Sandstone.	90°	1.0	Zincblende, dry ores, galena, siderite.	Horizontal slickensides on hanging wall.	Foot wall.	No. damage.
2	28 Oct. 1905.	31	1,059	6	44 North	40	"	"	80	1.0	ditto	Sandstone strata flat, with distinct transverse schistosity.	Hanging wall.	No damage.
3	4 Nov. 1905.	31	1,059	14	27 North	60	"	"	75	1.3	Pinched and barren.	The diabase overlies the sandstone on the hanging wall near the roof of the drift.	Hanging wall.	No damage.
4	11 Nov. 1905.	31	1,059	7	50 North	33	"	"	90	1.0	Zincblende, dry ores, galena, siderite.	A vertical fissure coursing at right angles. The vein cuts through the flat sandstones on the hanging wall of the vein. North of this fissure the sandstones show schistosity in two directions.	Hanging wall.	Slight cut on one workman but not serious enough to incapacitate him from work.
5	16 Nov. 1905.	32	1,109	27	5 North	105	"	"	90	1.6	ditto	Horizontal slickensides on hanging wall.	Foot wall.	No damage.
6	30 Nov. 1905.	31	1,059	9	45 North	38	"	"	80	1.3	ditto	Vein filling and hanging wall traversed by several fissures parallel in strike and dip to the vein itself.	Hanging wall.	No damage.

Digitized by Google

which act in this way and not the mild and clayey strata, and it would appear that sudden changes in the character and structure of the strata are responsible for the occurrence of air blasts.

The following list of all the air blasts which occurred during one month towards the end of 1905 in the Maria mine, gives, in connection with Fig. 4, a fair conception of their frequency, distribution and accompanying circumstances.

All of these air blasts occurred in the main Adalberti fissure, which as yet is the only vein opened up on the thirty-first and thirty-second levels.

Considering all of the circumstanses, the conclusion appears justified that the cause of these explosions is not only the pressure of the superincumbent rock mass, which is at right angles to the strata, but is due also to a stress parallel to the bedding planes and to the axis of the syncline. This view is supported by the fact that thin streaks or layers of calcite, filling clefts between the strata opened by end pressure, not infrequently accompany the bedding planes of the formation. Such streaks occur at a depth of 1,080 meters on the tenth stope of the Adalberti vein and on the thirty-second level, 110 meters north of the Maria shaft. This explanation is furthermore borne out by a marked slatiness of the country rock, cutting the stratification at an angle of 60° to 90°. Cases occur where the fissility of the rock is parallel to the main Adalberti vein, the bedding planes of the rock at the same time being nearly horizontal. When such ground is under high pressure, it tends to break up into an aggregation of flat slabs. These are the conditions which appear to favor the occurrence of air blasts, so that when they occur one or more of the above-mentioned flat slabs are likely to break loose and explode.

Preventive Measures.

The above-described conditions of stress demand serious consideration in planning and executing development work with a view to the greatest possible safety of the miners. They necessitate immediate removal of any broken ground in the stopes, especially where the walls are suspected of being favorable to air blasts. Such removal of rock and ore must be promptly followed up by the stope-filling, so that no open spaces are left except those absolutely necessary for handling the ore, for ladderways and for ventilation. It is, moreover, the custom to reduce as much as

Digitized by Google

possible the number of stopes *in simultaneous operation* and to distribute them over as large an area of the vein as possible. This is disadvantageous, as such an arrangement prevents concentration of the workings. Work at such points is prosecuted during one shift only, so that the ground is not disturbed for at least sixteen hours out of each twenty-four. This is for the purpose of allowing the stresses in the rock to equalize themselves. Only experienced and intelligent workmen are employed, and these are not changed without urgent reason, as it takes some time for men to become familiar with the ground. When air blasts are anticipated, shields are frequently used. These are made of planks firmly spiked together and are braced against the point of danger by means of stulls. Such precautions, together with others which have been employed from time to time, have enabled the management to meet the danger successfully.

Digitized by Google

THE DETERMINATION OF THE GEOMETRICAL CONSTANTS OF A CRYSTAL FROM ITS INTERFACIAL ANGLES.

By ALFRED J. MOSES.

The face symbols and elements of a crystal result either from angles between faces obtained with one-circle goniometers or from angles analogous to latitude and longitude obtained with two-circle goniometers.

For the purposes of instruction and especially in a course designed principally to rivet loose conceptions obtained in an elementary study of models and crystals it is better to use the one-circle goniometer and measure the very zones and angles actually seen on the crystal. It may also be said that neither the solution of the problems of the crystallographer * nor the obtaining of clear ideas as to structure, symmetry, indices and other crystal relations are necessarily connected with the deduction of the trigonometrical or other formulæ used. All this can be eliminated and a course presented which can be followed understandingly by any student able to use logarithmic tables.

The purpose of this paper is to present such a course under the principal divisions of:

I. Measurement of the Interfacial Angles.
II. Stereographic Projection.
III. Graphic Determination of Symmetry, Indices and Elements.
IV. Calculation of Axial Elements and Interfacial Angles.

I. THE MEASUREMENT OF THE INTERFACIAL ANGLES.

1. SELECTION OF THE CRYSTAL.

Before any measuring is done all available crystals are carefully examined to find:

(*a*) The most brilliant flawless crystals.

* "The chief problems of the crystallographer are: the determination of the face symbols and elements of the crystal when the angles are measured; or from a knowledge of the elements and the face indices to determine the true values of the angles." W. J. Lewis, "Crystallography," p. 161.

Digitized by Google

(*b*) Crystals which show rare faces or unusual combinations of faces or other peculiarities.

During and after selection the crystals are handled by either a pencil of wax or by the forceps, never by the fingers. If in any way blurred they are cleaned with chamois skin and, unless soluble therein, by alcohol.

2. SKETCHING THE CRYSTAL.

Each selected crystal is carefully studied with a hand-glass especially for:

1. Recurrence of similar groupings of faces, indicating symmetry.
2. Parallelism of edges, indicating zones.
3. Similarity of lustre or markings, indicating faces that belong to the same form.
4. Cleavages, parting and etchings.

A sketch is made, usually a horizontal projection of the crystal with some selected zone vertical. The bounding lines *a*, *b*, *c*, *d*, *e*, *f*, *g*, *h*, Fig. 2, which represent the vertical faces are drawn approximately at their true angles and apparently parallel edges between faces are drawn parallel. A letter or number is assigned to each face and thereafter represents it.

3. THE GONIOMETER.

Among "one-circle" goniometers preference is usually given to those in which the crystal is revolved about a vertical axis, and one of the best and simplest is the Fuess (4, *A*) shown * in Fig. 1.

The axes of the two telescopes, *C* and *T*, are in the same horizontal plane and intersect in the axis of rotation. If a crystal is attached by wax at *p*, and adjusted, as later described, so that an edge between two faces coincides with the axis of rotation, then a ray of light sent through *C* will be reflected into *T* for just *one* position of each face and the difference between the two readings of the graduated circle for these positions will be the supplement angle between the faces.

4. THE ADJUSTMENT.

Before the objective of *T* swings a lens which, when down, brings the crystal into focus. The crystal is attached by wax to the plate *p* as nearly as possible in the correct position. One of the faces of the angle to be measured is placed approximately parallel to one of the sliding screws, for instance *n*, and that screw is placed at right angles to the telescope.

* R. Fuess, Steglitz, near Berlin, marks 260, or about 65 dollars.

Digitized by Google

The lens on *T* is lowered and the crystal raised or lowered into the field after loosening the screw *d*. The crystal is then moved by *n* and tipped by the screw *k* of the corresponding circular arc until the edge appears to coincide with the vertical cross hair. The screw *a* is then loosened, the crystal turned 90° by the wheel *f* and the edge moved by *o* and tipped by the other circular arc

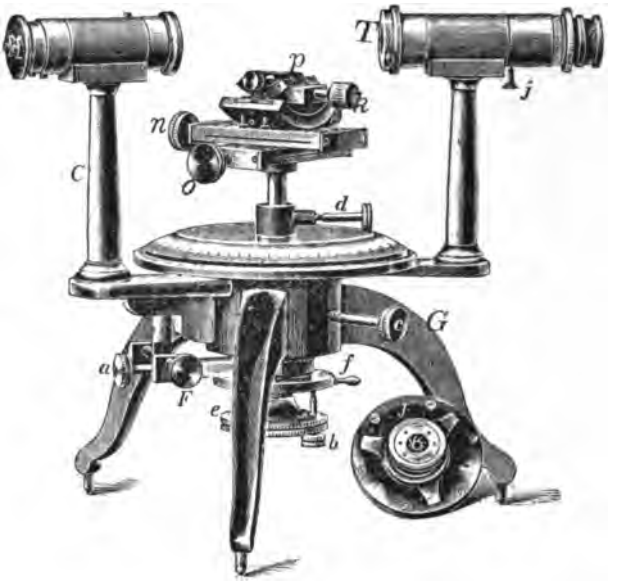


FIG. 1.

until again in coincidence with the vertical cross hair. This is repeated until through a rotation the edge and cross hair appear to coincide.

The lens is then raised and if the images of the signal from the faces can be bisected by the cross hairs the adjustment is satisfactory.

With small crystals it is not necessary to recenter on each edge, but is sufficient by a slight motion of the centering screws to make the vertical hair coincide wlth an imaginary central axis within the zone.

5. THE MEASURING.

The screw *G* is loosened and the telescope set at 100 to 120 degrees to the collimator *C*. The screw *a* is then loosened, the graduated circle and crystal are turned together by the wheel *f*,

Digitized by Google

until the reflected signal * is seen through the telescope, then *a* is tightened and the fine adjustment made by the tangent screw *F*. The vernier is then read and recorded.

The screw *a* is again loosened and the rotation continued until the signal is received from a second face; this is centered by *F* and *a* and recorded as before. *The difference between the two readings is the supplement angle between the faces.*

6. THE ORDER OF MEASUREMENT.

The zone first measured is usually one showing numerous or very well-developed faces. The sketch and the projection usually suggest other prominent zones. For instance, Fig. 2 suggests that

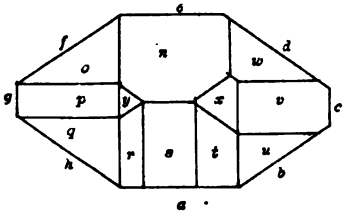


FIG. 2.

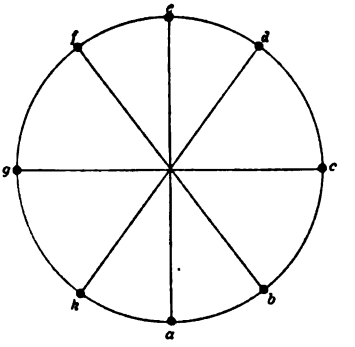


FIG. 3.

the first zone be followed by one of the two zones [*c*, *v*, *x*, *y*, *p*, *g*], and [*a*, *s*, *n*, *e*]. There are also zones [*u*, *t*, *s*, *r*, *q*] and [*w*, *n*, *o*].

7. CONNECTING THE ZONES.

Care must be taken to avoid assumptions as to the relative positions of two measured zones. In general a zone is determined by two non-parallel faces and a face by its angles with two known faces.

8. RECORDING THE MEASUREMENTS.

Two records should be kept, one in a note book and the other on circles of convenient size, one for each zone. For instance, for the zone [*a*, *b*, etc.] of the colemanite crystal, Fig. 2, draw a circle,

* After bringing the central line of the signal into coincidence with the vertical cross hair it is well to have the entire apparatus stand with the lamp lighted for 15 to 20 minutes. If there is a notable displacement of the signal from unequal heating of the outer and inner axles, readjust and let stand again until the centering can be maintained.

Digitized by Google

Fig. 3, and let the point a, represent the face a, the other faces b, c, may then be represented by other points b, c, on the circumference found by laying off arcs corresponding to the angles of the note book. Distortions will thereby be eliminated and the relations between the faces judged from these points. Opposite points will mean parallel faces, symmetrically related points will mean corresponding faces and so on.

The note book should provide columns for the readings and angles of three separate rotations, for instance:

ZONE $[a, b]$ COLEMANITE.

Face.	Quality of Signal.	First Rotation.		Second Rotation.		Third Rotation.		Average Angle.
		Reading.	Angle.	Reading.	Angle.	Reading.	Angle.	
a	Poor.	10° 27′		10° 28′		10° 27′		
			36° 03′		36° 02′		36° 04′	36° 03′
b	Good.	46 30		46 30		46 31		
			54 01		54 0		54 01	54 0⅔
c	Good.	100 31		100 30		100 32		
			53 58		53 59		53 59	53 58⅔
d	Perfect.	154 29		154 29		154 29		
			36 02		35 59		35 59	36 0
e	Poor.	190 31		190 28		190 28		
			35 57		35 59		35 59	35 58⅔
f	Good.	226 28		226 27		226 27		
			54 10		54 07		54 06	54 7⅔
g	Good.	280 38		280 34		280 33		
			53 59		54 05		54 05	54 03
h	Perfect.	334 37		334 39		334 38		

9. AVERAGING CORRESPONDING ANGLES.

It will usually happen that the reflections from the different faces concerned are of unequal distinctness. The brighter images can be more exactly centered and should have greater weight in the conclusions reached. The method of least squares is sometimes used but a simpler method is to assign a quality mark to each image of the signal. For instance, a perfect image may be 2, a good image 1, a poor image 0, and the proportionate value of any measurement may then be taken as the sum of the quality marks of the readings. These may be recorded in tabular shape, as in the following example:

The average angles obtained from the three readings by measuring the zone $[a, b]$ are given in the last column. The sketch, Fig. 2, and these angles indicate that bc, cd, fg and gh are corresponding angles. The process would be:

Digitized by Google

Angle.	Average.			Proportionate Value.	Product.		
bc	54°	0′	40″	1 + 1 = 2	108°	1′	20″
cd	53	58	40	1 + 2 = 3	161	56	0
fg	54	7	40	1 + 1 = 2	108	15	20
gh	54	3	0	1 + 2 = 3	162	9	0
				10	540°	21′	40″

Average 54° 2′ 10″

II. THE STEREOGRAPHIC PROJECTION.

In a few crystals of nearly ideal development and few faces it is possible to determine the grade of symmetry, axial elements and face indices by simple calculations from measured angles, but in more complex or unequally developed "distorted" crystals there is need of a method which shall eliminate the inequalities and not be confused by the numbers of faces.

Such a method is developed by assuming that the crystal is surrounded by a sphere, the centers of the sphere and the crystal coinciding, and that radii are drawn from the center perpendicular to each face of the crystal, cutting the surface of the sphere in points called the poles of the corresponding faces or "face-poles."

Evidently in such a construction the supplement angle between any two faces is measured by the arc of the great circle through their poles. The poles of all faces in one zone lie in the same great circle and the intersecting great circles form spherical triangles which can be solved by the rules of trigonometry.

But since it is not convenient to draw directly upon a sphere the imaginary surface is "projected" upon a plane by some method, usually either the "gnomonic," in which the radii are prolonged to intersect a plane tangent at the north pole, or the stereographic, in which the imaginary sphere with its face-poles and circles is projected upon a diametral plane.

1. STEREOGRAPHIC PROJECTION.

Let B, L, $\dot{B}$ represent the *primitive circle* or section of the sphere made by the plane of projection and P, $\dot{M}$, $\dot{P}$, etc., face-poles on the surface of the imaginary sphere.

From each face-pole a line is supposed to be drawn to the south pole S, and the point where this line pierces the "primitive circle" is the stereographic projection of that face-pole.

The radii perpendicular to the vertical faces of the crystal lie in the primitive circle and any face-pole L coincides with its stereo-

Digitized by Google

graphic projection. Radii perpendicular to any oblique face, however, lie in other planes and any face-pole as P is projected at P', the intersection of PS with the primitive circle.

By this method vertical zone-circles project as diameters, oblique zone circles as circles, each passing through both ends of a diame-

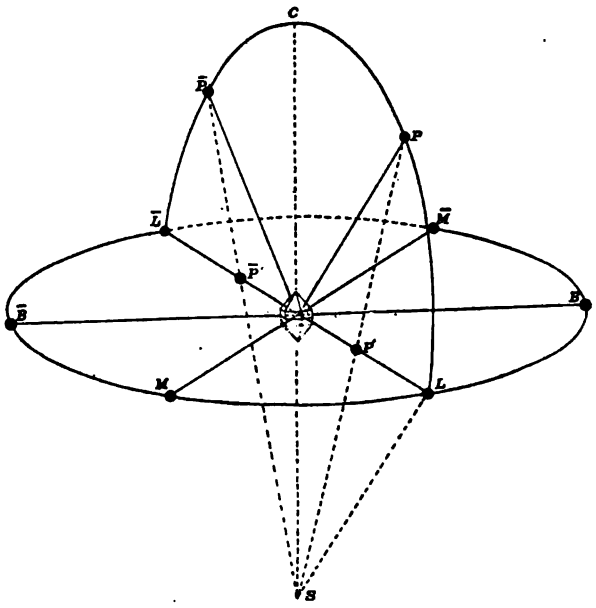


FIG. 4. Perspective of a Stereographic Projection.

ter and face-poles project as points. The entire projection is called a "stereogram."

The zonal relations and the spherical triangles are therefore all represented; and can be graphically solved or calculated.

2. PROJECTING THE POLES OF FACES WHICH ARE AT 90° TO PLANE OF PROJECTION.

Select the plane* of projection usually at 90° to a zone of numerous or well-developed faces. Draw a circle of any convenient diameter and let the point B, Fig. 5, be taken as the pole of a chosen vertical face. Lay off from B the supplement angles between this and the other vertical faces thus determining the poles L, M, B, etc. Draw diameters through these poles.

* The plane most used is at 90° to the so-called vertical axis. The position of this is determined by symmetry or arbitrarily by the choice of $A = 100$ and $B = 010$.

Digitized by Google

3. PROJECTING POLES ON KNOWN DIAMETERS.

If the face lies in a zone with a horizontal and a vertical face its pole projects on the diameter through the vertical face.

If the face makes equal angles with any two vertical faces, its pole projects on the diameter midway between the diameters through the poles of the two vertical faces.

In either case the distance of the projected pole from the center may be found by laying off *ab*, Fig. 5, equal to the angle with the horizontal face (or *Bb* equal the angle with the vertical face) of the same zone and drawing *bc*. Then is *OR* the desired distance.

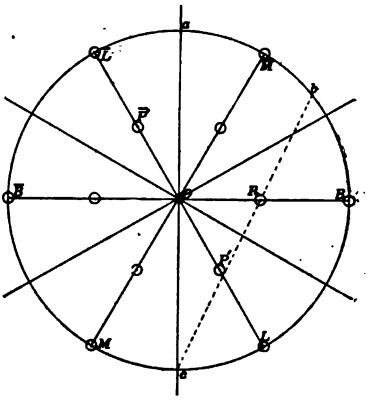
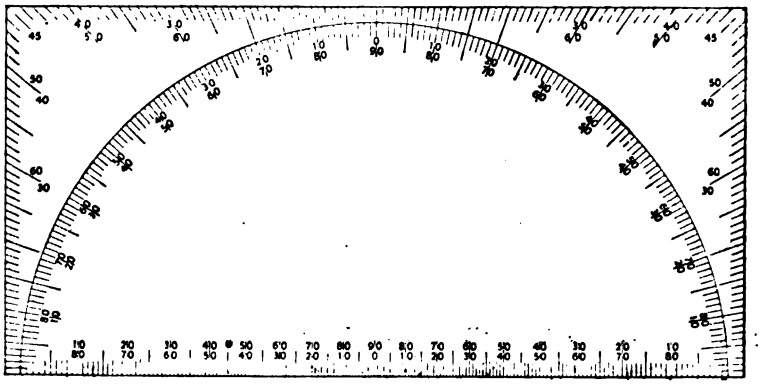


FIG. 5.

Or the distance may be laid off by a prepared scale of degrees projected on a diameter ("stereographic degrees"). In Fig. 6, the base line is placed with the zero point in coincidence with the



PROTRACTOR NO I, FOR PLOTTING STEREOGRAPHIC PROJECTIONS.
The graduation on the base line gives the stereographically projected degrees.
From * to 0 equals the chord of 90°.

FIG. 6.

center of the primitive circle and the distance corresponding to the angle with the horizontal (or vertical) face is measured from the center (or circumference).

Digitized by Google

4. DRAWING OBLIQUE ZONES THROUGH PROJECTED POLES.

As stated, p. 438, such zones project as arcs of circles, each passing through both extremities of the same diameter. The centers of these circles lie on the radius normal to this diameter. Thus in Fig. 7 the center of the zone [*BPO*] is on the radius at 90° to $B\dot{B}$ at its intersection *S* with the normal bisector of $\dot{B}P$ (or of *OP* or *OB*, etc.).

Penfield prepared a protractor of celluloid with projected semicircles for each degree. If this be laid as in Fig. 7, with its straight line coincident with *BB*, then by counting from the circumference of the primitive circle to the zone, the corresponding radius may be measured on a prepared scale.

For instance, in Fig. 7 the zone through *P* and *O*, counting from the circumference, is a little beyond the 39th degree. The corresponding radius is measured on the scale.

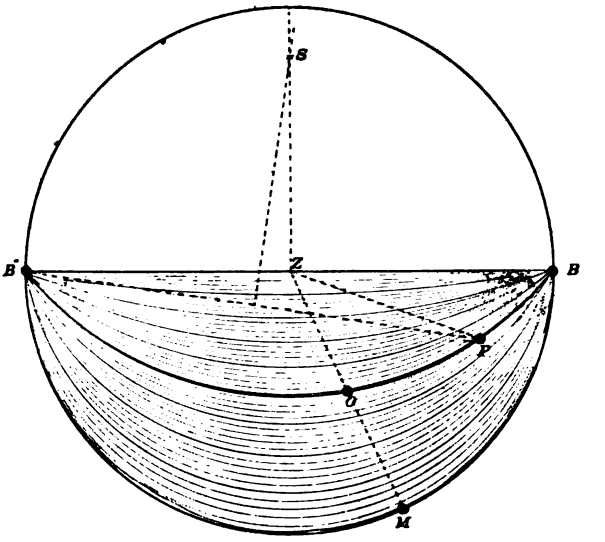


FIG. 7.

5. PROJECTING OTHER POLES OF THESE OBLIQUE ZONES.

If the face lie in two of these zones its pole is at their intersection. If it make a known angle with some other face of the zone it may be located by means of a celluloid protractor of projected small circles.†

For instance, to find the projection of *Q* a face on the zone [*LP*], Fig. 8, the measured angle *PQ* being 70 degrees, place the

* The [] indicate a zone.

† Penfield Protractor No. II., New Haven, Conn.

Digitized by Google

protractor so that the ends of its indicated diameter coincide with the intersections of the zone circle and the primitive circle. The pole P is on the small circle 47, hence Q must be on circle

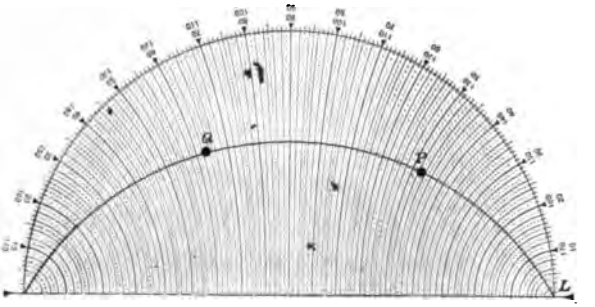


FIG. 8.

$47 + 70 = 117$. The *direction* is always evident from inspection of the crystal.

6. PROJECTING POLES NOT IN ZONES DRAWN.

The angles PQ and PR of any such face P with two known faces Q and R are essential. Evidently two small circles on the surface of the sphere drawn around Q and R with PQ and PR respectively will intersect in the desired point P. The problem is therefore to find the *projection* of these two small circles, their intersection being the projection of P.

Small circles also project as circles. Let Q and R, Fig. 9, be known poles. Let the measured angles be $PQ = 42° 30'$, $PR = 48°$. Draw radii through Q and R and measure CQ and CR with protractor 1, Fig. 6. In Fig. 9 these values are 55° 30′ and 79°.

There must be two points m and n on the prolonged radius CQ which are the two ends of a projected diameter of the circle around Q and two similar points h and s of the circle around R. The distances * of these from the center in "stereographic" (projected) degrees are:

$$Cm = CQ - PQ = 55° 30' - 42° 30' = 13°$$
$$Cn = CQ + PQ = 55 \quad 30 + 42 \quad 30 = 98$$
$$Ch = CR - PR = 79 \quad 0 - 48 \quad 0 = 31$$
$$Cs = CR + PR = 79 \quad 0 + 48 \quad 0 = 127$$

* The distances are laid off on the radius with Protractor 1 or with scale 3 which is simply Protractor 1 carried beyond 90° to 160°.

Digitized by Google

If *m* and *n* are the ends of a projected diameter and the entire projection a circle the center of that circle is at *o* half way between. Similarly the center of the projected circle around *R* is at *t*, half way between *h* and *s*.

The desired pole is at one of the two intersections of these two

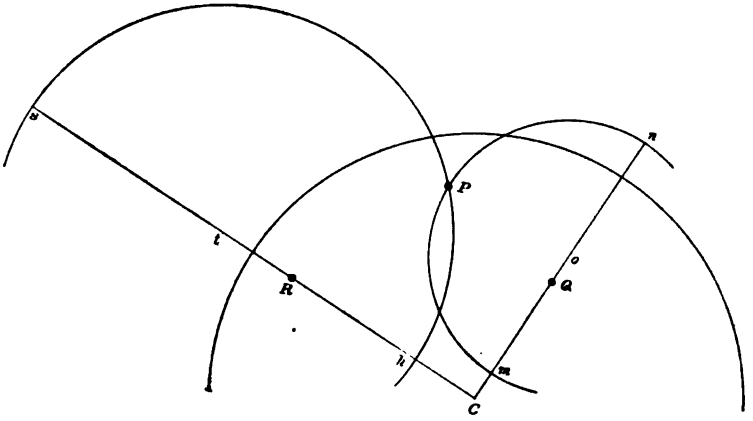


FIG. 9.

small circles. Usually a mere inspection will tell which. In rare cases it may be necessary to obtain the angle with a third face and construct a third small circle.

III. GRAPHIC DETERMINATION OF THE SYMMETRY AND THE FACE INDICES FROM THE STEREOGRAM.

1. DETERMINING THE SYSTEM OF CRYSTALLIZATION.

This can usually be determined by two tests directly from the stereogram.

Test 1.—If by revolving a paper tracing of the projection on the projection itself about a needle through the coincident centers, all the poles of the tracing coincide with those of the projection *more than once* in a complete revolution, then an axis of 2-fold, 3-fold, 4-fold or 6-fold symmetry exists in the crystal perpendicular to the plane of projection.

Test 2.—If by folding the paper tracing on *any* diameter *all* the poles of the one half cover those of the other, then this diameter is the trace of a plane of symmetry perpendicular to the plane of projection.

Digitized by Google

The following table will usually identify the "system" unless a very unimportant zone has been chosen as the vertical zone.

Symmetry of Center.	Diameters of Symmetry.	System.
Six-fold	Six or none	Hexagonal
Four-fold	Four, two or more	Isometric or Tetragonal
Three-fold	Three or none	Hexagonal or Isometric
Two-fold	Two or none	Isometric or Orthorhombic
Two-fold	None	Monoclinic
None	One	Monoclinic
None	None	Triclinic

In projections of isometric crystals there are three points 90° apart which are surrounded by the same grouping of planes. In tetragonal projections there are two such points.

2. CHOOSING THE ELEMENTARY FACES.

The three axial planes, $A = 100$, $B = 010$ and $C = 001$, and the "parametral" plane 111 are essential to the determination of axis,* parameters † and indices.‡

Choosing A, B and C. — Assuming the plane of projection to be at 90° to A and B, the following rules may be given:

A and B will always be projected on the circumference of the primitive circle and C within the circle.

TRICLINIC. — Any three such poles.

MONOCLINIC. — A and C on the same diameter and $AB = 90°$.

ORTHORHOMBIC. — $AB = BC = AC = 90°$.

TETRAGONAL. — $AB = BC = AC = 90°$. A and B interchangeable.§

HEXAGONAL. — $AB = 60°$, $AC = BC = 90°$. A and B interchangeable.

ISOMETRIC. — $AB = BC = AC = 90°$. A, B and C interchangeable.

It may be best to choose as A, B or C a plane not actually present in the crystal. For instance a plane parallel to one or equally inclined to two planes of symmetry.

Choosing the Parametral Plane 111. — Any pole *within* the triangle A, B, C may be taken as 111 or instead of this any two poles *on*

* Axes are imaginary lines through the center parallel to the intersections of A, B and C.

† The chosen parameter or unit face 111 cuts the axes at certain finite distances a, b and c from the center. These distances are called the *parameters* of the crystal and are expressed as a ratio $a : b : c$.

‡ The indices are numbers which, divided into the parameters term by term, give the relative intercepts of the corresponding face on the axes.

§ That is each surrounded by a similar group of poles.

Digitized by Google

AB. *BC* or *AC* (but not both on the same arc) may be chosen as 110, 011 or 101 respectively and from these the position of 111 will result, see p. 446.

3. DETERMINING THE INDICES BY ZONAL EQUATIONS.*

(*a*) For every zone there are three numbers called zone indices, which are derived from the expression for the direction of intersection † of any two faces of the zone. The values of these numbers for two faces (hkl) and $(h'k'l')$ are $u = kl' - lk'$, $v = lh' - hl'$, $w = hk' - kh'$.

(*b*) The indices of a face which lies in the zones [uvw] and [u'v'w'] are $h = uv' - vu'$, $k = vw' - wv'$, $l = wu' - uw'$.

These values may be obtained by cross multiplication of the twice written indices, striking off end terms and reading down alternately from left to right and from right to left.

For instance, if a face lie in a zone with 133 and 311 and also in a zone with 335 and 395, its indices must be 355, for the zone indices of the first zone are

$$\begin{array}{cccccc} 1 & 3 & 3 & 1 & 3 & 3 \\ & \times & \times & \times & & \\ 3 & 1 & 1 & 3 & 1 & 1 \end{array} \qquad \begin{array}{l} u = 3-3 = 0 \\ v = 9-1 = \bar{8} = [0\bar{8}\bar{8}] = [01\bar{1}] \\ w = 1-9 = \bar{8} \end{array}$$

Similarly the zone indices of the second zone are $u'v'w' = [\bar{5}03]$. Therefore the values of the indices of the face are

$$\begin{array}{cccccc} 0 & 1 & \bar{1} & 0 & 1 & \bar{1} \\ & \times & \times & \times & & \\ \bar{5} & 0 & 3 & \bar{5} & 0 & 3 \end{array} \qquad \begin{array}{l} h = 3-0 \\ k = 5-0 = 355 \\ l = 0+5 \end{array}$$

(*c*) If a face (pqr) lies in a zone [uvw] its indices must satisfy the equation $pu + qv + rw = 0$.

This may supply a missing index, for instance, the face $(3k1)$ is found to be in the zone $[1\bar{1}\bar{1}]$; substituting in the equation $3 \times 1 + k \times \bar{1} + \bar{1} \times 1 = 0$, whence $k = 2$.

4. DETERMINING THE INDICES IN THE ZONES THROUGH A, B AND C.

(*a*) *Any zone passing through two of A, B and C.*

Every face in the zone will have that index zero which is zero in both. That is :

* Miller's Treatise on Crystallography, 1839, pp. 7, 8 and 10.

† If a parallelogram be constructed on the axes with the center as a vertex with sides equal u*a*, v*b*, w*c*, the diagonal through the center is the direction of intersection of the wo faces.

Digitized by Google

For zone $[AB]$ the type symbol is hko,
" " $[BC]$ " " " " okl,
" " $[AC]$ " " " " hol.

(b) *For any zone through one of A, B or C.*

The ratio of the two indices, which are zero for A, B or C, is constant for all faces of the zone. Hence:

For a zone through A, k/l is constant for all faces.

For a zone through B, h/l is constant for all faces.

For a zone through C, h/k is constant for all faces.

The indices of a face at the intersection of two such zones will result if in each zone a second face is known. The desired values may be obtained by writing the indices of the two known faces, omitting the term in each not part of the constant ratio, and then multiplying the corresponding pair for one index and diagonal pairs for the other two indices.

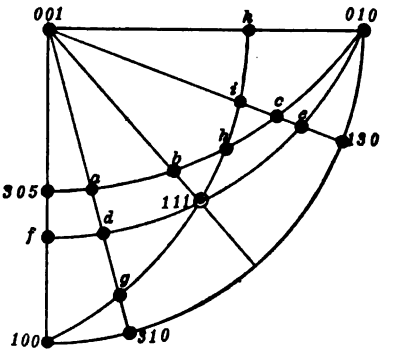


FIG. 10.

EXAMPLE. — In Fig. 10, let the pinacoids and (111), (310), (305), and (130), be known, to find the indices of planes projected at a, b, c, d, e, f, g, h, i, k. All calculations are either like h in zones [010 305] and [100 111], or like i in zones [001 130] and [100 111].

$$\begin{array}{ccccc} 3 & - & 5 & & \\ & \times & & & h = 355 \\ - & 1 & 1 & & \\ \hline 3 & 5 & 5 & & \end{array} \qquad \begin{array}{ccccc} 1 & 3 & - & & \\ & \times & & & i = 133 \\ - & 1 & 1 & & \\ \hline 1 & 3 & 3 & & \end{array}$$

Similarly $a = 315$, $b = 335$, $c = 395$, $d = 313$, $e = 131$, $f = 101$, $g = 311$ and $k = 011$.

In the hexagonal system the third index is omitted.

EXAMPLE. — $hk\bar{i}l$ lies in the zone $10\bar{1}0 : 02\bar{2}1$ and also in the zone $01\bar{1}0 : 11\bar{2}\bar{1}$. Omitting $\bar{i}$ and writing the constant ratios as before, there result

$$\begin{array}{ccccc} - & 2 & 1 & & \\ & \times & & & hkl = 121 \\ 1 & - & 1 & & \\ \hline 1 & 2 & 1 & & \end{array} \qquad hk\bar{i}l = 12\bar{3}1.$$

Digitized by Google

5. GRAPHIC DETERMINATION* OF THE INDICES OF A "GROUP."

It will usually happen that the indices of some faces cannot be obtained by zonal equations, certain factors being lacking. Simple graphical constructions can be made which will give a fresh start to the determination by intersecting zones. These constructions involve the idea of what are here called "Groups."

A group may be defined as a set of planes, $P = hkl$, $H = okl$, $K = hol$, $L = hko$, Fig. 11, in which the ratios of $h : k : l$ are the same. By the method of preceding paragraphs, if zone circles are drawn through any pole, $P = hkl$ and AB and C, respectively, these circles intersect the sides of the triangle ABC in points H, K, L, the indices for which are as stated.

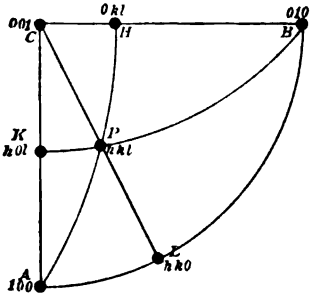


FIG. 11.

The indices of all the faces P, H, K and L of a group result from constructions involving any two of H, K or L, provided the parametral group, in which $h\,k\,l = 111$ has been chosen or determined.

(a) DETERMINATION OF $\frac{h}{k}$ FROM POSITION OF L.

The method is the same in all systems if A and B are in the circumference of the primitive circle.

Find T, Figs. 12, 13, 14 and 15, the intersection of the radius through 110 and the tangent at A. Take RT parallel to CA as equal unity. Then the radius through L will cut this line RT at a point T' such that

$$RT' = \frac{h}{k}\left(\text{or } RT' = \frac{\text{first index}}{\text{second index}}\right).\dagger$$

*These graphic solutions were first described by A. J. Moses and A. F. Rogers in this journal, 24, 11–22.

†This form is better for isometric, tetragonal and hexagonal in which there is a different convention of $h > k$ rather than h, first axis, k second.

Digitized by Google

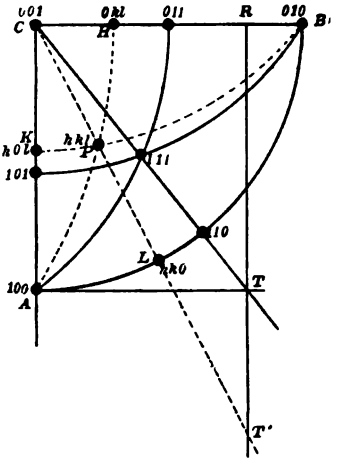


FIG. 12.

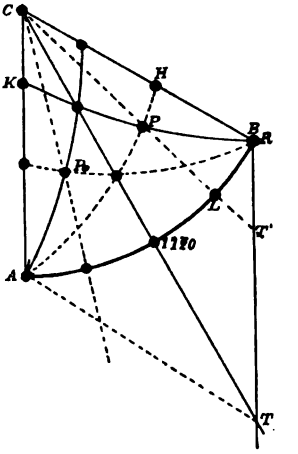


FIG. 13.

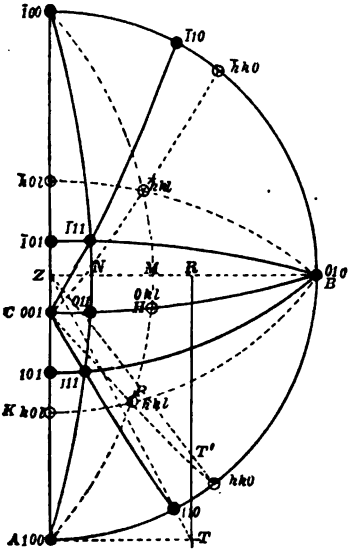


FIG. 14.

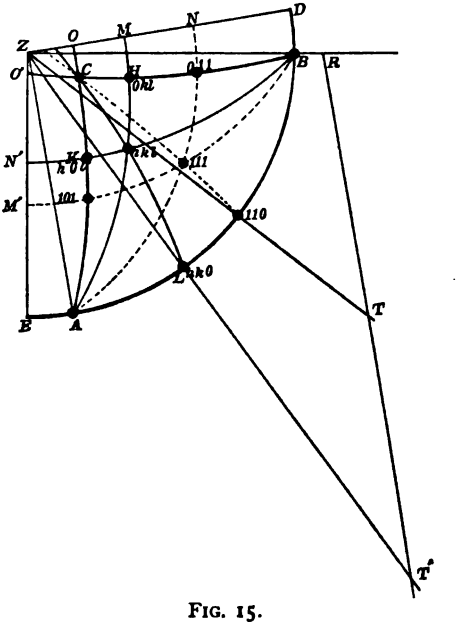


FIG. 15.

(*b*) DETERMINATION OF $\frac{k}{l}$ FROM POSITION OF *H*.

For all isometric, tetragonal, orthorhombic or hexagonal crystals measure with protractor 1, Fig. 6, the angle from the center *C* to 011, and in the fourth quadrant of the projection (or upon a circle with the same radius) lay off this angle from *A'*, Fig. 16, and find

Digitized by Google

T the intersection of the corresponding radius with the tangent at B. Take RT parallel CB as unity. Similarly measure the angle CH with the protractor, lay this off from A' and find the intersection T', Fig. 16, of the corresponding radius with RT, then

$$RT' = \frac{k}{l}.$$

In the *monoclinic*, Fig. 14, the ratio $\frac{k}{l}$ results by measuring the values in stereographic degrees of ZN and ZM (from the center to the zone circles through 011 and H) laying these off from A', Fig. 16, and proceeding as before.

In the *triclinic* a radius ZD, Fig. 15, is drawn at 90° to AZ and on this the values in stereographic degrees from the center to the

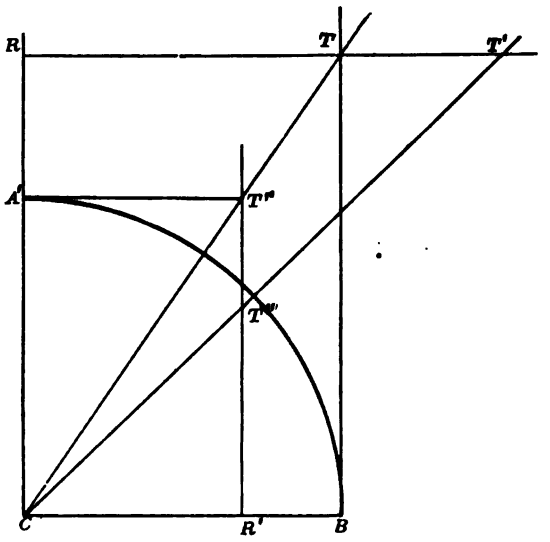


FIG. 16.

zone circles through C, 011 and H, that is: ZO, ZN and ZM, are measured with protractor 1. The construction is thereafter as follows:

In the fourth quadrant of the projection or upon any circle of the same radius lay off these angles from Z, Fig. 17, determining the points O, N and M. Draw and prolong radii through each.

Through the intersection T of the radius SN and a line from B parallel SO draw a line RT parallel SB. This line is the scale line

Digitized by Google

and RT is its unity. Then the point of intersection T' of SM with this determines

$$RT' = \frac{k}{l}$$

(*c*) DETERMINATION OF $\frac{h}{l}$ FROM THE POSITION OF K.

If $\frac{h}{k}$ and $\frac{k}{l}$ have been determined this is not needed, otherwise the construction for *isometric*, *tetragonal*, *hexagonal* and *orthorhombic* crystals is that of Fig. 16 but using the angles $C \wedge 101$ and CK instead of $C \wedge 011$ and CH.

In the *monoclinic*, the construction is exactly that of Fig. 17 The stereographic angles ZC, $Z \wedge 101$ and ZK, Fig. 14, are measured with protractor I and laid off from Z on the circumference, Fig. 17. The scale line through T and the values $RT' = \frac{h}{l}$ are determined as described under Fig. 17, O, N, M respectively corresponding now to C, 101 and K.

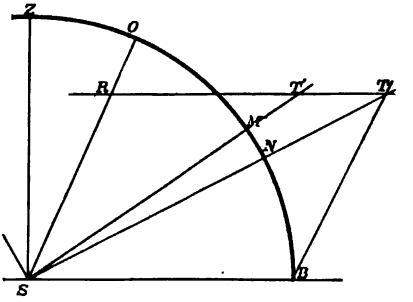


FIG 17.

In the *triclinic* the construction is strictly that for $\frac{k}{l}$, measuring on ZE, Fig. 15, at 90° to ZB the values ZO', ZM' and ZN' and laying these off in Fig. 17 in place of ZO, ZN and ZM respectively.

6. GRAPHIC DETERMINATION OF THE PARAMETERS.

Tetragonal. $\dot{c} = AT''$, Fig. 16, in which $A'CT'' = 001 \wedge 011$ or $001 \wedge 101$.

Orthorhombic. $\dot{a} = AT$, Fig. 12.
$\dot{b} = AT''$, Fig. 16, if $A'CT'' = 001 \wedge 011$.

Hexagonal. $\dot{c} = AT''$, Fig. 16, if $A'CT'' = 0001 \wedge 11\bar{2}1$.
$\dot{c} = AT'' \times 0.866$, Fig. 16, if $A'CT'' = 0001 \wedge 10\bar{1}1$.

Monoclinic. $\beta = AC$, Fig. 14.
$\dot{b} = A'T''$, Fig. 16, if $A'CT'' = ZN$ of Fig. 14.
$\frac{\dot{a}}{\dot{c}} = SR$, Fig. 17, if $ZST = Z \wedge 101$ of Fig. 14.

Digitized by Google

Triclinic. For α and β, Fig. 21, measure the stereographic degrees with protractor 1, cut from a radius drawn at 90° to A and B.

For γ measure* the plane angle between tangents at C to AC and BC.

$\frac{1}{\dot{c}} = SR$, Fig. 17, in construction for $\frac{k}{l}$, p. 448.

$\frac{a}{c} = SR$, Fig. 17, in construction for $\frac{h}{l}$, p. 449.

In all constructions the radius is taken as unity.

IV. THE CALCULATION OF AXIAL ELEMENTS AND OF IMPORTANT INTERFACIAL ANGLES.

In the figures following, $A = 100$, $B = 010$, $C = 001$ and the "group" $P = hkl$, $H = okl$, $K = hol$ and $L = hko$. The projections are on planes at 90° to A and B.

1. THE ORTHORHOMBIC SYSTEM.

Taking the parameter $\bar{b} = 1$ the axial elements are $\dot{a}$ and $\dot{c}$.

(*a*) AXIAL ELEMENTS FROM ANGLES OF H, K AND L, FIG. 18

$$\dot{a} = \frac{h}{k} \tan AL\,; \quad c = \frac{l}{k} \tan CH\,; \quad \frac{\dot{c}}{\dot{a}} = \frac{l}{h} \tan CK,$$

In these:

$$2AL = LL'''\,; \quad 2CH = HH'\,; \quad 2CK = KK'.$$

(*b*) AXIAL ELEMENTS FROM ANGLES OF P, FIG. 18.

$$\dot{a} = \frac{h \cos BP}{k \cos AP}, \qquad \dot{c} = \frac{l \cos BP}{k \cos CP},$$

in which $AP = 90° - \frac{PP'}{2}$; $BP = 90° - \frac{PP'''}{2}$; $CP = \frac{PP''}{2}$,

(*c*) ANGLE BETWEEN ANY TWO FACES $P = hkl$ AND $Q = h'k'l'$.

Calculate AL and BH for P and, similarly, AL_1 and BH_1 for Q by formulæ under (*a*). Calculate CP and CQ by

* Prolong the arc AC, draw a chord through two points equidistant each side of A, on AC and the line parallel to this through A will be the tangent; similarly for the other tangents.

Digitized by Google

$$\tan CP = \frac{\cot BH}{\sin AL}; \quad \tan CQ = \frac{\cot BH_1}{\sin AL_1}.$$

Then *

$$\text{Cos } PQ = \cos CP \cos CQ + \sin CP \sin CQ \cos (AL - AL_1).$$

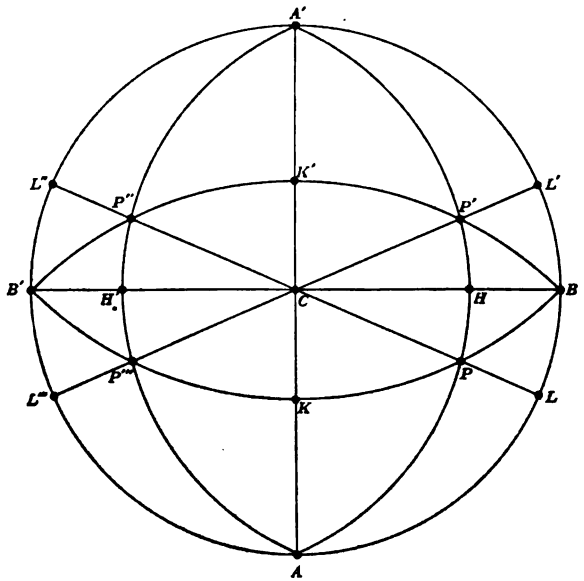


FIG. 18.

If P and Q lie in a zone with A, B or C then:

$$\frac{\tan AP}{\tan AQ} = \frac{kh'}{hk'} = \frac{lh'}{hl'}, \text{ for zone with } A;$$

$$\frac{\tan BP}{\tan BQ} = \frac{lk'}{kl'} = \frac{hk'}{kh'}, \text{ for zone with } B;$$

$$\frac{\tan CP}{\tan CQ} = \frac{kl'}{lk'} = \frac{hl'}{lh'}, \text{ for zone with } C.$$

That is if one angle is known, the other may be calculated.

If P and Q are faces of the same form PQ becomes one of:

$$PP' = 2(90° - AP); \; PP'' = 2CP; \; PP''' = 2(90° - BP),$$

* Another but usually more tedious general formula is

$$\text{If } S = h^2c^2 + k^2c^2a^2 + l^2a^2, \quad S' = h'^2c^2 + k'^2c^2a^2 + l'^2a^2,$$

$$\text{Cos } PQ = \frac{hh'c^2 + kk'c^2a^2 + ll'a^2}{\sqrt{SS'}}.$$

Digitized by Google

hence if any angles of the formulæ in (*a*) or (*b*) are known the required value can probably be calculated. The first formula in (*c*) connects (*a*) and (*b*).

(*d*) FINDING POSITION OF ANY FACE OF KNOWN INDICES.

Any two of *AL*, *CH* or *CK* or any two of *AP*, *BP* or *CP* determine the position of a face *P*, Fig. 11. The formulæ of (*a*) and (*b*) may be solved for these.

---

2. THE TETRAGONAL SYSTEM.

Taking the parameter $a = 1$ the only axial element is *c*.

The formulæ of the orthorhombic apply if *a* is made equal unity ($a = 1$).

CONSTANT ANGLES IN ZONE [*A B*].

The angles in the prismatic zone are constant for all species. These angles for all values *h* and *k* may be calculated by

$$\tan AL = \frac{k}{h}$$

and each face *L* will have its associated *L'* for which $AL' = 90° - AL$. The most frequent values are:

L	*AL*	*L*	*AL*
110	45° 0′	530	30° 57′.8
870	41 11.1	740	29 44.7
650	39 48.3	210	26 33.9
540	38 39.6	310	18 26.1
430	36 52.2	410	14 02.2
750	35 32.2	710	8 07.9
320	33 41.4	810	7 07.5

---

3. THE ISOMETRIC SYSTEM.

In this system the parameters are equal and the angles between the axes are right angles.

(*a*) ANGLE* BETWEEN ANY TWO FACES $P = hkl$ AND $Q = h'k'l'$.

The formulæ of the orthorhombic apply if both *a* and *c* are made unity; thus the general formula becomes:

$$\cos PQ = \frac{hh' + kk' + ll'}{\sqrt{(h^2 + k^2 + l^2)(h'^2 + k'^2 + l'^2)}}.$$

* The angles for *PQ* being the same for all isometric species, the prominent angles such as $AP(hkl — 100)$, $OP(hkl — 111)$ and the angles between adjacent faces of the same form have been calculated and are recorded — for instance, *Dana's System*, 6th edition, pp. xxi–xxvi; Goldschmidt's *Krystallographische Winkeltabellen*, under the species.

Digitized by Google

(*b*) THE CONSTANT ANGLES *AL*, *BH* AND *CK*.

The angles *AL*, *BH* and *CK* (or their functions *AP*, *BP* and *CP*) for any group result from the indices as follows:

$$\tan AL = \frac{\text{second}}{\text{first}}; \quad \tan BH = \frac{\text{third}}{\text{second}}; \quad \tan CK = \frac{\text{first}}{\text{third}}.$$

The angles *AL*, *BH*, *CK* for the common forms result easily from the table on p. 452 for *AL* by the rule *AL* for $L = hko$ is *BH* for $H = ohk$ and *CK* for $K = koh$.

Thus for $L = 870$, $AL = 41° 11.1'$. This is also *BH* for $H = 087$ and *CK* for $K = 708$.

---

4. THE HEXAGONAL SYSTEM.

Taking the parameter $a = 1$ the only axial element is $\dot{c}$.

(*a*) AXIAL ELEMENT FROM ANGLES OF *K* OR *S*, FIG. 19.

$$\dot{c} = \frac{l}{h} \cos 30° \tan CK = \frac{l}{2h} \tan CS.$$

In these

$$\sin CK = \sin \frac{KK'''}{2} = 2 \sin \frac{KK'}{2} = \sin \frac{KK''}{2} \times 1.1547;$$

$$\sin CS = \sin \frac{SS'''}{2} = 2 \sin \frac{SS'}{2}.$$

(*b*) AXIAL ELEMENT FROM ANGLES OF *P*, FIG. 19.

$$\dot{c} = \frac{l}{h + k} \tan CP \sin (60° + AL).$$

In this

$$\tan AL^* = \frac{k}{2h + k} \sqrt{3}; \quad CP = 90° - PL = \tfrac{1}{2} PP^{VI}.$$

(*c*) ANGLE *PQ* BETWEEN ANY TWO FACES $P = hkil$, $Q = h'k'i'l'$

$$\cos PQ = \frac{3ll' + 2c^2(hk' + kh' + 2hh' + 2kk')}{MM'},$$

in which $M = \sqrt{3l^2 + 4c^2(h^2 + k^2 + hk)}$; M' has a corresponding value.

---

* See values of *AL* next page.

Digitized by Google

If P and Q are in a zone which passes through C

$$\tan CQ = \tan CP \frac{h'l}{hl'}.$$

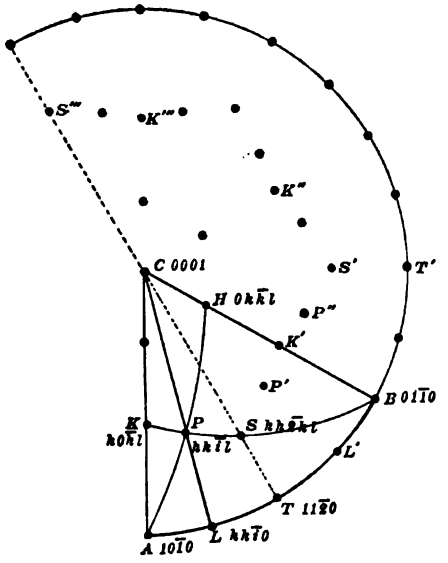


FIG. 19.

(*d*) CONSTANT ANGLES IN ZONE [*AB*], FIG. 19.

These may be calculated from formula for *AL* and from *AL'* = 60° − *AL*.

Face Indices.	Angle *AL*.	Angle *AL'*.
10.1.$\bar{1}$1.0	4° 42.8′	55° 17.2′
51$\bar{6}$0	8 56.9	51 3.1
41$\bar{5}$0	10 53.6	49 6.4
31$\bar{4}$0	13 53.8	46 6.2
52$\bar{7}$0	16 6.1	43 53.9
21$\bar{3}$0	19 6.4	40 53.6
32$\bar{5}$0	23 24.8	36 35.2
54$\bar{9}$0	26 19.6	33 40.4
11$\bar{2}$0	30 0	30 0

(*e*) FINDING POSITION OF ANY FACE OF KNOWN INDICES.

Any two of *AL*, *BH* or *CK* or any two of *AP*, *BP* or *CP* determine the position of a face *P*, Fig. 11.

$$\tan AL = \frac{k}{2h + k}\sqrt{3}; \quad \tan CK = 1.1547\frac{h}{l}c; \quad \cot BH = 1.1547\frac{k}{l}c.$$

Digitized by Google

$$\cos AP = \frac{c(2h+k)}{M};\ \cos BP = \frac{c(h+2k)}{M};\ \cos CP = \frac{l\sqrt{3}}{M};$$

in which

$$M = \sqrt{3l^2 + 4c^2(h^2 + k^2 + hk)}.$$

---

5. THE MONOCLINIC SYSTEM.

Taking the parameter $\dot{b}$ as unity the axial elements are the values of $\dot{a}$ and $\dot{c}$ and of the acute angle β between the vertical and clino axes

(*a*) THE VALUE OF β.

$\beta = AC$, Fig. 20.

$$\cos\beta = \frac{\cos CL}{\cos BL}.$$

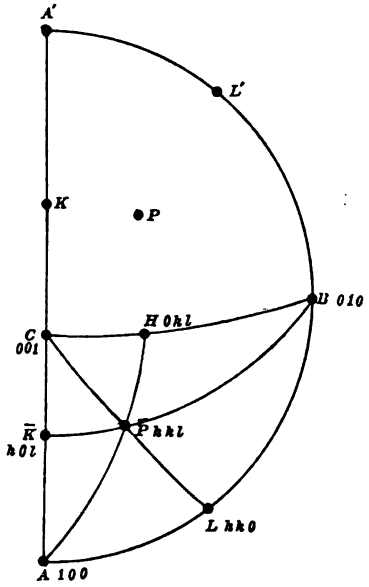


FIG. 20.

(*b*) ELEMENTS $\dot{a}$ AND $\dot{c}$ FROM ANGLES OF H, K AND L, FIG. 20.

$$\dot{a} = \frac{h}{k}\frac{\cot BL}{\sin\beta};\ \text{in which } 2BL = LL'.$$

$$\dot{c} = \frac{l}{k}\frac{\tan CH}{\sin\beta};\ \text{in which } 2CH = HH'.$$

$$\frac{c}{\dot{a}} = \frac{l}{h}\frac{\sin CK}{\sin AK} = \frac{l}{h}\frac{\sin CK}{\sin A'K}.$$

Digitized by Google

(*c*) ELEMENTS $\dot{a}$ AND $\dot{c}$ FROM ANGLES OF P AND $\bar{P}$.

$$\dot{a} = \frac{\dot{c}h}{l} \frac{\sin \Sigma}{\sin (\beta - \Sigma)}; \text{ in which } \cos \Sigma = \frac{\cos A\bar{P}}{\sin B\bar{P}}.$$

$$\dot{a} = \frac{\dot{c}h}{l} \frac{\sin \Sigma'}{\sin (\beta + \Sigma')}; \text{ in which } \cos \Sigma' = \frac{\cos A'P}{\sin B\bar{P}}.$$

$$\dot{c} = \frac{l}{k} \cot \theta; \text{ in which } \cos \theta = \frac{\cos BP}{\sin AP} = \frac{\cos BP}{\sin A'P}.$$

(*d*) ALL AXIAL ELEMENTS FROM THREE ANGLES $B\bar{P}$, $A\bar{K}$, $C\bar{K}$, FIG. 20.

$$\dot{a} : \dot{c} = \frac{h}{k} \frac{\cot BP}{\sin C\bar{K}} : \frac{l}{k} \frac{\cot B\bar{P}}{\sin A\bar{K}}; \quad \beta = C\bar{K} + A\bar{K}.$$

Equally well

$$\dot{a} : \dot{c} = \frac{h}{k} \frac{\cot BP}{\sin CK} : \frac{l}{k} \frac{\cot BP}{\sin A'K}; \quad \beta = 180° - (CK + A'K).$$

(*e*) ANGLE PQ BETWEEN ANY TWO FACES, $P = hkl$, $Q = h'k'l'$, FIG. 20,

If P and Q are on a zone through B,

$$\tan BQ = \frac{h'k}{hk'} \tan BP = \frac{l'k}{lk'} \tan BP; \quad PQ = BP - BQ.$$

That is, PQ results if either BP or BQ and the indices are known.

If P and Q are on a zone through C,

$$\cot C\bar{P} = \frac{l}{h} \cot C\bar{Q} + \frac{h-l}{h} \cot CL,$$

$$\cot CP = \frac{l}{h} \cot C\bar{Q} - \frac{h-l}{h} \cot CL,$$

as before $PQ = CP - CQ$ or $P\bar{Q} = C\bar{P} - C\bar{Q}$.

For other zones when cotangent formula is tedious.

Calculate $A\bar{K}$ and $B\bar{P}$ for $\bar{P}$ and $A\bar{K}'$, $B\bar{Q}$ for $\bar{Q}$ by formulæ under (*f*), then

$$\cos \bar{P}\bar{Q} = \cos B\bar{P} \cos B\bar{Q} + \sin B\bar{P} \sin B\bar{Q} \cos (A\bar{K}' - A\bar{K}).$$

Digitized by Google

(*f*) FINDING THE POSITION OF ANY FACE $\bar{P} = hkl$, FIG. 20.

By the angles $B\bar{P}$, $A\bar{K}$ and $C\bar{K}$

$$\tan \tfrac{1}{2}(A\bar{K} - C\bar{K}) = \tan (45^\circ - \theta) \tan \tfrac{1}{2}(A\bar{K} + C\bar{K}),$$

in which

$$\tan \theta = \frac{h\dot{c}}{l\dot{a}}; \quad A\bar{K} + C\bar{K} = \beta.$$

Therefore

$$A\bar{K} = \tfrac{1}{2}(A\bar{K} - C\bar{K}) + \tfrac{1}{2}(A\bar{K} + C\bar{K}),$$

$$C\bar{K} = \tfrac{1}{2}(A\bar{K} - C\bar{K}) - \tfrac{1}{2}(A\bar{K} + C\bar{K}),$$

$$\text{Cot } B\bar{P} = \frac{\dot{a}k}{h} \sin C\bar{K} = \frac{\dot{c}k}{l} \sin A\bar{K}.$$

By the angles $A\bar{P}$, $B\bar{P}$ and $C\bar{P}$

$$\cos A\bar{P} = \frac{hc + la \cos \beta}{M},$$

$$\cos B\bar{P} = \frac{kac \sin \beta}{M},$$

$$\cos C\bar{P} = \frac{la + hc \cos \beta}{M},$$

in which

$$M = \sqrt{h^2c^2 + k^2a^2c^2 \sin^2 \beta + l^2a^2 + 2hlac \cos \beta}.$$

---

6. THE TRICLINIC SYSTEM.

The axial elements are the parameters a, b and c, in which b is taken as unity and the angles between the axes $\alpha = b \wedge c$, $\beta = a \wedge c$ and $\gamma = b \wedge c$.

(*a*) FINDING α, β AND γ FROM AB, BC AND AC, FIG. 21.

Denote $\frac{1}{2}(AB + BC + AC)$ by S then

$$\cot \frac{\alpha}{2} = \sqrt{\frac{\sin (S - AC) \sin (S - AB)}{\sin S \sin (S - BC)}},$$

$$\cot \frac{\beta}{2} = \cot \frac{\alpha}{2} \cdot \frac{\sin (S - BC)}{\sin (S - AC)},$$

Digitized by Google

$$\cot\frac{\gamma}{2} = \cot\frac{a}{2}\cdot\frac{\sin(S-BC)}{\sin(S-AB)},$$

or

$$\cos\alpha = \frac{\cos BC - \cos AB\cos AC}{\sin AB\sin AC},$$

$$\cos\beta = \frac{\cos AC - \cos AB\cos BC}{\sin AB\sin BC},$$

$$\cos\gamma = \frac{\cos AB - \cos AC\cos BC}{\sin AC\sin BC}.$$

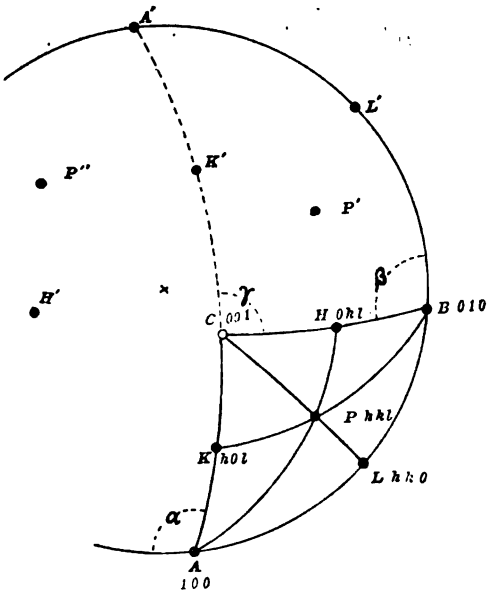


FIG. 21.

(*b*) ELEMENTS *a* AND *c* FROM ANGLES *AB*, *BC* AND *AC* AND TWO OF *AP*, *BP* AND *CP*, FIG. 21.

In one of the triangles *APB*, *BPC* and *APC* calculate the two angles not at *P* (for instance in *BPC* calculate *CBP* and *BCP*).

Let

$$S = \frac{BC + CP + BP}{2},$$

then

Digitized by Google

$$\sin\frac{CBP}{2}=\sqrt{\frac{\sin(s-BC)\sin(s-BP)}{\sin BC\sin BP}},$$

$$\sin\frac{BCP}{2}=\sqrt{\frac{\sin(s-BC)\sin(s-CP)}{\sin BC\sin CP}}.$$

But, $CAB=180°-\alpha$; $CBA=180°-\beta$; $ACB=180°-\gamma$, also $ACP=ACB-BCP$ and $ABP=CBA-CBP$.

Substituting these in two of

$$\frac{\sin ABP}{\sin CBP}=\frac{al}{ch};\quad \frac{\sin CAP}{\sin BAP}=\frac{ck}{l};\quad \frac{\sin ACP}{\sin BCP}=\frac{ak}{h};$$

the values of a and c result if h, k and l are known.

(*c*) ELEMENTS a AND c FROM ANGLES OF H, K AND L, FIG. 21.

From H, α and β,*

$$c=\frac{l}{k}\left[\sin(AB-X)\tan Y\sin\alpha+\cos\alpha\right],$$

in which

$$\cot X=\frac{\cot BH}{\cos\beta}\quad\text{and}\quad\sin Y=\frac{\cos BH}{\cos X}.$$

From K,† α and β,

$$\frac{c}{a}=\frac{l}{h}(\sin R\tan S\sin\beta+\cos\beta),$$

in which

$$\cos R=\frac{\cos BK}{\sin S}\quad\text{and}\quad\cos S=\sin\alpha\sin AK.$$

From L,‡ γ and BC

$$a=\frac{h}{k}(\cot M\sin\gamma+\cos\gamma).$$

If $s=\frac{1}{2}(BC+CL+BL)$,

$$\sin\frac{M}{2}=\sqrt{\frac{\sin(s-CL)\sin(s-BC)}{\sin BC\sin CL}}$$

* For H' use $-\cos\alpha$ and BH'.

† For K' use $-\cos\beta$, BK' and AK'.

‡ For $h\bar{k}o$ use $-\cos\gamma$ and BL'

Digitized by Google

(*d*) ELEMENTS *a* AND *c* FROM ANGLES* OF *P*, FIG. 21.

$$a = \frac{ch}{l} \frac{\sin Z}{\sin (\beta + Z)}, \text{ in which}$$

$$\cos Z = \frac{\cos AP + \cos AB \cos BP}{\sin AB \sin BP}.$$

$$\frac{c}{a} = \frac{l}{h}(\sin M \tan N \sin \beta + \cos \beta), \text{ in which}$$

$$\tan M = \frac{\cos AP}{\cos BP \sin AB} - \cot AB; \quad \sin N = \frac{\cos BP}{\cos M}.$$

(*e*) TO FIND THE ANGLES *AP*, *BP* AND *CP*, FIG. 21.

First: Calculate CH, BH, AK, CK, AL, BL as follows:

$$\cot CH = \frac{l \sin AB}{ck \sin AC \sin BC} + \cot BC,$$

$$\cot AK = \frac{ch \sin BC}{al \sin AB \sin AC} + \cot AC,$$

$$\cot AL = \frac{h \sin BC}{ak \sin AC \sin AB} + \cot AB;$$

$$BH = BC - CH; \quad CK = AC - AK; \quad BL = AB - AL.$$

Second: Calculate AH, BK and CL as follows:

$$\cos AH = \cos AC \cos CH + \sin AC \sin CH \cos (180° - \gamma),$$
$$\cos BK = \cos AB \cos AK + \sin AB \sin AK \cos (180° - \alpha),$$
$$\cos CL = \cos BC \cos BL + \sin BC \sin BL \cos (180° - \beta).$$

Third: Calculate AP, BP and CP as follows:

$$\tan \tfrac{1}{2}(PH - AP) = \tan (45° - \varphi) \tan \tfrac{1}{2}(AH); \quad \tan \varphi = \frac{\sin AB}{\sin BH} \frac{al}{ch},$$

$$\tan \tfrac{1}{2}(PK - BP) = \tan (45° - \psi) \tan \tfrac{1}{2}(BK); \quad \tan \psi = \frac{\sin BC}{\sin CK} \frac{h}{ak},$$

$$\tan \tfrac{1}{2}(PL - CP) = \tan (45° - \theta) \tan \tfrac{1}{2}(CL); \quad \tan \theta = \frac{\sin AC}{\sin AL} \frac{ck}{l}.$$

Then

$$AP = \tfrac{1}{2}AH + \tfrac{1}{2}(PH - AP),$$
$$BP = \tfrac{1}{2}BK + \tfrac{1}{2}(PK - BP),$$
$$CP = \tfrac{1}{2}CL + \tfrac{1}{2}(PL - CP).$$

* Substitute for corresponding terms in above as follows: In $\bar{h}kl(P')$: A', P', L', and $-\cos \beta$. In $hkl(P'')$: A', B', P'', L'' and $-\cos \beta$. In $h\bar{k}l(P''')$: B' P''', and L'''.

† The signs of the functions must be considered.

Digitized by Google

BOOK REVIEWS.

Electric Transmission of Water Power. By A. S. ADAMS, A. M., Mem. A.S.E.E. McGraw Publishing Co., New York, 1906. 335 pages, 105 illustrations. Price, $3.00.

This book as its title is meant to show, deals with the various pieces of apparatus employed in the construction and operation of the transmission lines of hydro-electric power plants; it also gives plans of various power plants, substations, etc. The treatment of the subject matter is in most instances, however, of such a general character that the publication is more for general reading than for reference. M. A.

High Tension Power Transmission. McGraw Publishing Co., New York, 1906. Vol. 2, 315 pages, 108 illustrations. Price, $2.50.

This book is a republication of a series of papers and discussions on high-tension power transmission presented before the International Electrical Congress at St. Louis, 1904. While as stated the contents of this work have previously appeared in the transactions of the above Congress, they are of such value that their publication in a separated volume can only be commended. A book of this type, embodying as it does the experiences and opinions of the greatest authorities in this field of engineering, should be carefully read and placed within ready reach as a reference book by all members of the electrical profession.

M. A.

Digitized by Google

Digitized by Google

VOL. XXVII. No. 4. JULY, 1906.

GE... UNI... SEP 19 190...

THE

SCHOOL OF MINES QUARTERLY.

A

JOURNAL OF APPLIED SCIENCE.

BOARD OF EDITORS.

A. J. MOSES, Prof. of Mineralogy.
J. F. KEMP, Prof. of Geology.
R. PEELE, Prof. of Mining.
R. E. MAYER, Adj. Prof. of Drawing.
E. WALLER, Analytical Chemist.
W. H. FREEDMAN, E.E.,
T. H. HARRINGTON, Tutor in Drawing.

Managing Editor, R. E. MAYER,
Business Manager, T. H. HARRINGTON.

CONTENTS:

Geology of Pioche, Nevada, and Vicinity. By Fred J. Pack 365
The Historical Development of General Chemistry. By Wilhelm Ostwald 388
The Application of Metallography to Opaque Minerals. By William Campbell 414
Stresses in the Country Rock as the Cause of Air Blasts in the Mines at Pribram, Bohemia. By Hugo Stefan 423
The Determination of the Geometrical Constants of a Crystal from its Interfacial Angles. By Alfred J. Moses 432
Book Reviews 461

COLUMBIA UNIVERSITY
NEW YORK CITY.

Registered at the New York Post Office as Second Class Matter.

TWO DOLLARS PER YEAR. FIFTY CENTS PER NUMBER.
All Remittances should be made payable to Order of "The School of Mines Quarterly."

Digitized by Google

Baldwin Locomotive Works

BURNHAM, WILLIAMS & CO., PHILADELPHIA, PA., U. S. A.

Cable Address "Baldwin" Philadelphia

LOCOMOTIVES

OF EVERY DESCRIPTION

Electric Locomotives built in conjunction with Westinghouse Electric and Mfg. Co. Electric Motor and Trailer Trucks for Railway and Suburban Service.

STANDARD STEEL WORKS

HARRISON BUILDING, PHILADELPHIA, PA.

Steel Tired Wheels **Solid Forged Rolled Steel Wheels**

Locomotive Tires **Forgings** **Railway Springs** **Castings**

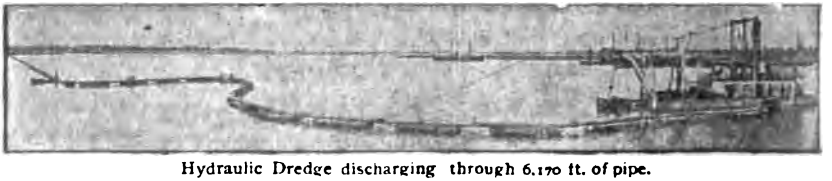
BEST QUALITY AND GREATEST EFFICIENCY GUARANTEED
THEREFORE, MORSE TOOLS ARE THE MOST ECONOMICAL

MORSE TWIST DRILL AND MACHINE CO.

NEW BEDFORD, MASS., U. S. A.

We make and carry in stock various styles of Arbors, Reamers, Chucks, Counterbores, Countersinks, Dies, Three and Four Groove Drills, Drills with Oil Holes, Jobbers' Drills, Letter Drills, Wire Drills, Gauges, Mandrels, Metal Slitting Saws, Cutters with Solid and Inserted Teeth—Axial, Radial, Angular, Form and Gang Cutters; a full line of Taps, Adjustable Tap Wrenches, Opticians', model Makers' and Machinists' Screw Plates and Dies, Solid Pipe Dies and Solid Machine or Bolt Dies, Tools for Turret Head Machines and many others; being made, as are all of our tools, of the best material and by the best workmen, their accuracy and effectiveness are assured.

ATLANTIC, GULF AND PACIFIC CO.



Hydraulic Dredge discharging through 6,170 ft. of pipe.

ENGINEERS AND CONTRACTORS.

SPECIALTIES: Dredging, Dredging Machines, Land Reclamation, Docks, Piers, Foundations, Bridges.
Correspondence solicited.

MAIN OFFICE: PARK ROW BUILDING, NEW YORK.

BRANCH OFFICES: 220 MARKET STREET, SAN FRANCISCO, CAL.

95 YESLER WAY, SEATTLE, WASH. *MANILA, PHILIPPINE ISLANDS.*

Digitized by Google

Hanger.

P. PRYIBIL,

512-524 West 41st St., New York, N. Y.

MANUFACTURER OF

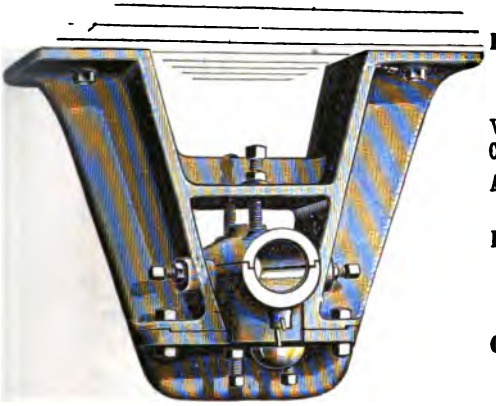
Complete Power Transmission Machinery.

CAN FURNISH ANY SIZE DESIRED.

All bearings are self-oiling, having a smooth bore equal to a gun-barrel finish. A large stock kept constantly on hand.

Self-Oiling Hanger Box.

Will run six months with one oiling.



Head Shaft Hanger.

Estimates Furnished.

Write for Catalogue—

A, Woodworking Machinery:

B, Brass, Ivory and Horn Working Machinery:

C, Power Transmission Machinery.

Sliding Hook Post Hanger.

Jenkins Bros. Valves

are made of high-grade steam metal, have interchangeable parts, and full opening. Our new **extra heavy** valves—both brass and iron body—for high steam and hydraulic pressures, are the heaviest valves of this class on the market.

Special illustrated price-list of extra heavy valves sent on application. All valves bearing our trade mark absolutely guaranteed.

JENKINS' BROS., New York, Boston, Philadelphia, Chicago, London

---

The WESTON Standard VOLTMETERS and AMMETERS

For Portable and Laboratory Use.

WATTMETERS & VOLTMETERS

For Alternating and Direct Current Circuits.

STATION AMMETERS and VOLTMETERS.

Weston Electrical Instrument Co.,

Main Office and Works, Waverly Park, Newark, N.J.

NEW YORK OFFICE: 74 Cortlandt St.
LONDON BRANCH: Andrey House, Ely Place, Holborn
PARIS, FRANCE E. H. Cadiot, 12 Rue St. George.
BERLIN: European Weston Electrical Instrument Co., No. 88 Ritterstrasse.

Digitized by Google

"Graphite as a Lubricant"

The newest publication of the Dixon Co., treating in detail of the exact action and value of Dixon's Pure Flake Graphite."

"The Perfect Solid Lubricant."

A copy will be forwarded upon request. Samples of the various Graphite Lubricants freely furnished for trial and test.

Joseph Dixon Crucible Co., Jersey City, N. J.

Please mention this paper.

C. L. BERGER & SONS

Successors to BUFF & BERGER,

PRECISE

Engineering and Surveying Instruments

No. 37 Williams St., Boston, Mass.

They secure in their Instruments: *Accuracy of division, Simplicity in manipulation: Lightness, combined with strength; Achromatic telescope, with high power; Steadiness of Adjustment under varying temperatures; stiffness to avoid any tremor, even in a strong wind, and thorough workmanship in every part.*

These instruments are in general use by the U. S. Government Engineers, Geologists, and Surveyors, and the range of instruments, as made by them for River, Harbor, City, Bridge, Tunnel Railroad and Mining Engineering, as well as those made for Triangular or Topographical Work and Land Surveying, etc., etc., is larger than that of any other firm in the country.

Illustrated Manual and Catalogues sent.

THE

Roessler & Hasslacher Chemical Co.

Importing and Manufacturing Chemists,

CYANIDE AND ALL MINING CHEMICALS

100 William St., NEW YORK

CHRISTIAN BECKER,

Successor to Becker & Son and to Becker Bros.

MANUFACTURER OF

Balances and Weights of Precision,

for Assayers, Chemists, Jewelers and all who require accuracy of weight. In use in all colleges and in the scientific departments of the U. S. Government.

ONLY FACTORY: NEW ROCHELLE, N. Y.

OFFICE: 5 and 7 MAIDEN LANE, NEW YORK CITY.

Illustrated Price List on Application.

Digitized by Google

In the 20th Century

Up-to-Date Factories, Laboratories and Metallurgical Works will use none but

Gas-Blast Furnaces!

The Automatic "AMERICAN OIL GAS MACHINE" NOW supplies the

IDEAL FUEL GAS

for 1100 different kinds of GAS-BLAST FURNACES.

Pamphlets and Catalogues on application to

AMERICAN GAS FURNACE CO.

23 JOHN STREET, NEW YORK CITY.

F. W. Devoe & C. T. Raynolds Co.,

Cor. Fulton and William Streets, New York,

and 176 Randolph Street, Chicago

MANUFACTURERS OF

ARTISTS' MATERIALS,

SUPPLIES FOR

Oil and Water Color Painting, Pastel and Miniature Painting, Etching, Ornamenting and Designing. Materials for Tapestry Painting, Repousse Tools and Lustre Paints.

—MANUFACTURERS OF FINELY PREPARED—

ARTISTS' OIL COLORS IN TUBES,

FINE BRUSHES FOR OIL and WATER COLOR PAINTING,

Dry Colors, Colors in Oil and Japan Fine Varnishes, Ready Mixed Paints, White Lead, &c.

—MANUFACTURERS OF—

MATHEMATICAL INSTRUMENTS,

Engineers' Supplies and Draughtsmen's Materials,

T Squares, Triangles, Scales, Tapes, Cross Section Papers, Theodolites, Transits, Levels, Etc.

Digitized by Google

Steam Pipe Covering

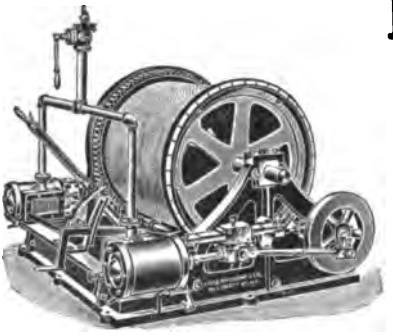
85 per cent. Magnesia Asbestos Air Cell
Mineral Wool Asbestos Papers
Hair Felt Brine Pipe, etc. SOLD AND APPLIED

ROBERT A. KEASBEY COMPANY
Buffalo, 13 Terrace • • New York, 100 N. Moore St.

McIntosh, Seymour & Co.

STEAM ENGINES

AUBURN, N. Y.



LIDGERWOOD HOISTING ENGINES....

BUILT TO GAUGE ON DUPLICATE PART SYSTEM—QUICK DELIVERY ASSURED

STANDARD FOR QUALITY AND DUTY.

The "Lidgerwood" Hoisting Engines are strictly High Grade in every particular and accepted as the Standard Modern High Speed Hoisting Engines, both as regards High Duty and Economy, Durability and Simplicity, combined with ease and Rapidity of Operation. Over 26,000 in Use. For Pile Driving, Bridge and Dock Building, Mining, Railroad, and Contractors' Use. *Send for latest Catalogue.*

LIDGERWOOD MFG. CO.,
Warerooms: 96 Liberty St.. NEW YORK. U. S. A.

Montana Ore Purchasing Co.

F. AUG. HEINZE, Pres. and Gen'l. Mgr. ARTHUR P. HEINZE, Sec.
JOHN MACGINNISS, Vice Pres. STANLEY GIFFORD, Treas.

Authorized Capital, $2,500,000; Issued, $2,020,835.
Surpus, $1,250,000.

PURCHASERS, SMELTERS AND REFINERS OF

Copper, Silver and Gold Ores.

SMELTING WORKS: BUTTE, MONT.
OFFICE: BUTTE, MONT.

Digitized by Google

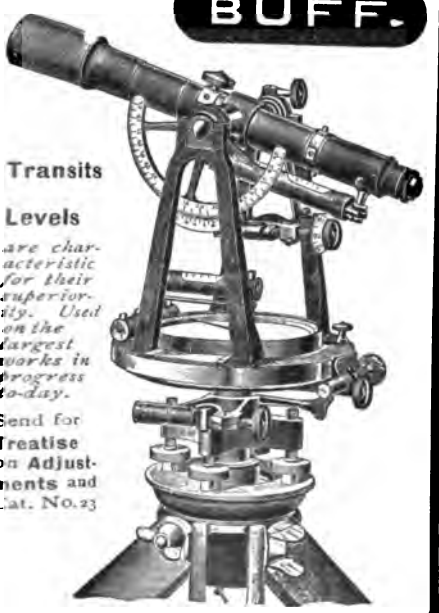
Vacuum Oils

Are known and used wherever machinery runs. They are the standards of value throughout the whole world. They lubricate most on every kind of machinery; not the same oil for all machines but the right oil for each class. Vacuum Oils are made to fit every condition. That is why they are used wherever machinery is in operation. Admiral Dewey's Fleet used them at the Battle of Manila. The best users everywhere will have no others when they know their values.

Vacuum Oils are made at Rochester and Olean, N. Y., and distributed throughout the world from local branches. Abroad they are distributed from one hundred and twelve foreign warehouses, and at home they are sold in every city. The reason Vacuum Oils are everywhere used is: they lubricate most. They reduce friction to the limit and save power. They are always uniform and to be depended upon. They do their work better than all others, and cheaper when the work done is figured. Other oils may sell for less by the gallon, but Vacuum Oils cost the least by the day.

Vacuum Oil Company,
Rochester, N. Y.

BUFF.



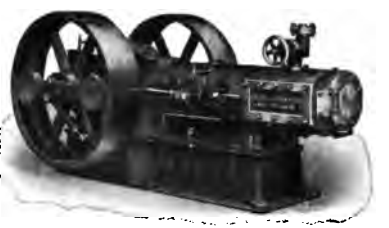
Transits

Levels

are characteristic for their superiority. Used on the largest works in progress to-day.

Send for **Treatise** on **Adjustments** and Cat. No. 23

BUFF & BUFF MFG. CO,
J. P. Station, BOSTON, MASS.



Sturtevant Horizontal Centre-Crank Engines

are entirely enclosed, provided with watershed partitions, equipped with forced lubrication and absolutely free from the throwing of oil. Removable plates on the sides of the frame, and handholes with oil-tight covers in the crank case, provide easy access to the reciprocating parts. Large wearing surfaces are provided throughout; the main bearings and those for crank pin and valve slide being babbitted with Sturtevant White Metal. The crank-shaft is forged in a single piece with extra large pin and with balancing discs shrunk on. A Rites governor regulates the speed.

B. F. STURTEVANT CO.,

Boston, Mass.

General Office and Works,
HYDE PARK, MASS.

New York Philadelphia Chicago London

Designers and Builders of Heating, Ventilating, Drying and Mechanical Draft Apparatus; Fans, Blowers and Exhausters; Steam Engines, Electric Motors and Generating Sets; Fuel Economizers; Forges, Exhaust Heads, Steam Traps, Etc.

Digitized by Google

CHEMICALS & CHEMICAL APPARATUS

ASSAYERS' MATERIALS

NEW! IMPORTANT!

Wanner's Optical Pyrometer

the only RELIABLE Instrument indicating exactly the highest temperatures.

Made to register up to 2000° C. and 4000° C. and over. Portable and convenient; giving quick results; no special knowledge required.

Sole selling agents for the lately discovered KUNZITE, a lilac-colored, transparent spodumene; beautiful crystals from $1.00 upwards.

CURIE'S RADIUM SALTS from 40 × activity to 1.800.000 ×.

SPINTHARISCOPES, X-RAY TUBES, FLUORESCENT SCREENS, ETC.

NEW! PATENTED!

... SECTIONAL ...
Electric Laboratory Furnaces

FOR ALL PURPOSES. WRITE FOR CIRCULAR

Stender's Reagent Bottles

with absolutely *indelible* black lettering.

SCHOTT & GENOSSEN'S Famous Jena Laboratory Glassware.
C. A. F. KAHLBAUM'S C. P. Chemicals and Reagents.
CARL SCHLEICHER & SCHÜLL'S C. P. Filters.
FRANZ SCHMIDT & HAENSCH'S Polariscopes, Etc.
DESMOUTI'S & CIE'S Purest Hammered Platinum.
GREINER & FRIEDRICHS' Fine Stopcock and Graduated Ware.

BALANCES AND WEIGHTS, ETC.

OUR SPECIALTY
COMPLETE LABORATORY OUTFITS

Everything Needed for the Laboratory

Do not fail to visit our Radium and other exhibits at the Louisiana Purchase Exposition at St. Louis, Mo.

EIMER & AMEND, 205-211 Third Ave. Cor. 18th Street New York

Digitized by Google

SECOND EDITION REVISED

8vo, Cloth, 254 pp. with Diagrams and Figures. Price, $3.00 net.

GAS ENGINE DESIGN

BY

CHARLES EDWARD LUCKE, Ph.D.

Mechanical Engineering Department, Columbia University, New York City.

Contents

Chapter 1.—Power, Efficiency, Economy. From the initial contract specifications for power, economy and adaptability to service, this chapter shows how proper displacements for the power can be calculated, and probable economy predicted.

Chapter 2.—Forces in the Engine due to Gas Pressure. Variations of pressure throughout the stroke, with their causes are discussed, and means given for drawing probable indicator cards of new engines.

Chapter 3.—Forces due to Mass and Motion and their combination with Gas Pressure Forces. The forces due to revolving and reciprocating masses are calculated and their effect in shaking, rocking and vibrating of frame determined. The eliminating of these unbalanced kinetic forces by balancing methods is followed by the effects of the same forces on turning effort. Changes of turning effort for difference in fuels, ignition, mixture, load, speed and weight of parts are also here calculated.

Chapter 4.—Stresses in, and Dimensions of Parts. Application of the previous chapters to determining stresses, with theoretic considerations of the properties of materials, give the form of the formula for the dimensions of the parts. The constants of these formulas are determined by practice, giving practical formulas for the dimensions of all standard parts. These formulas as finally presented, are in such form as to be of immediate application by the designer.

IN PRESS

12mo. Cloth, about 350 pp., - - Illustrated

LONG DISTANCE
ELECTRIC POWER TRANSMISSION

Being a Treatise on the

Hydro-Electric Generation of Energy;

ITS

Transformation, Transmission and Distribution

BY

R. W. HUTCHINSON, Jr.

Formerly Chief Instructor Electrical Engineer Institute of N. Y.; Associate Member of the American Institute of Electrical Engineers, and Member of the American Electrochemical Society.

D. VAN NOSTRAND CO., Publishers and Booksellers,

23 Murray and 27 Warren Sts., NEW YORK

Digitized by Google

Technical experience is essential to good accounting.

The staff representatives of our Company have both skill and experience. They are also given the constant supervision of the management.

Every accounting matter is satisfactorily and economically administered by

THE AUDIT COMPANY OF NEW YORK

"Oldest and foremost corporation engaged in auditing in the county."

HOME OFFICE,
43 CEDAR STREET, NEW YORK.

Western Office	Philadelphia Office	New England Office
New York Life Building,	Arcade Building	Easton Building,
La Salle & Monroe Sts.,	15 & Market Streets,	15 State Street,
Chicago.	Philadelphia.	Boston.

WEST PULVERIZING MACHINE CO.

220 BROADWAY,
NEW YORK.

METALLOGRAPHY

TAUGHT BY CORRESPONDENCE IN SEVENTEEN LESSONS

For further particulars address

ALBERT SAUVEUR

ROTCH BUILDING CAMBRIDGE, MASS

Digitized by Google

ATLAS
Portland Cement

IS THE STANDARD
AMERICAN BRAND

Endorsed and Used by all

CIVIL AND CITY ENGINEERS

Throughout the Country.

The U. S. Government Gives it the Preference Over All Other Brands.

Atlas Portland Cement Company

30 Broad Street, New York.

SEND FOR PAMPHLET.

JEFFREY ENDLESS PAN CONVEYER

Screening
Drilling
Mining
Elevating
Crushing

Catalogues Free

Correspondence Solicited

Conveying Coal from Upper to Lower Tipple

THE JEFFREY MFG. CO., Columbus, Ohio, U. S. A.

New York Chicago Boston Denver St. Louis

Digitized by Google

Columbia University in the City of New York

Columbia University includes both a college and a university in the strict sense of the words. The college is Columbia College, founded in 1754 as King's College. The university consists of the Faculties of Law, Medicine, Philosophy, Political Science, Pure Science and Applied Science. The point of contact between the college and the university is the senior year of the college, during which year students in the college pursue their studies, with the consent of the college faculty, under one or more of the faculties of the university.

Barnard College, a college for women, is financially a separate corporation; but, educationally, is a part of the system of Columbia University.

Teachers College, a professional school for teachers, is also, financially, a separate corporation; and also, educationally, a part of the system of Columbia University.

Each college and school is under the charge of its own faculty, except that the Schools of Mines, Chemistry, Engineering and Architecture are all under the charge of the Faculty of Applied Science. For the care and advancement of the general interests of the university educational system, as a whole, a Council has been established, which is representative of all the corporations concerned.

I. THE COLLEGES.

Columbia College offers for men a course of four years, leading to the degree of a Bachelor of Arts. Candidates for admission to the college must be at least fifteen years of age, and pass an examination on prescribed subjects, the particulars concerning which may be found in the annual circular of information.

Barnard College, founded in 1889, offers for women a course of four years, leading to the degree of Bachelor of Arts. Candidates for admission to the college must be at least fifteen years of age, and pass an examination on prescribed subjects, the particulars concerning which may be found in the annual circular of information.

II. THE UNIVERSITY.

In a technical sense, the Faculties of Law, Medicine, Philosophy, Political Science, Pure Science and Applied Science, taken together, constitute the University. These faculties offer advanced courses of study and investigation, respectively, in (*a*) private or municipal law, (*b*) medicine, (*c*) philosophy, philology and letters, (*d*) history, economics and public law, (*e*) mathematics and natural science, and (*f*) applied science. Courses of study under all of these faculties are open to members of the senior class in Columbia College. Certain courses under the non-professional faculties are open to women who have taken the first degree. These courses lead, through the bachelor's degree, to the university degrees of Master of Arts and Doctor of Philosophy. The degree of Master of Laws is also conferred for advanced work in law done under the Faculties of Law and Political Science together.

III. THE PROFESSIONAL SCHOOLS

The Faculties of Law, Medicine and Applied Science, conduct respectively the professional schools of Law, Medicine and Mines, Chemistry, Engineering and Architecture, to which students are admitted as candidates for professional degrees on terms prescribed by the faculties concerned. The faculty of Teachers College conducts professional courses for teachers, that lead to a diploma of the university.

1. The School of Law, establised in 1858, offers a course of three years in the principles and practice of private and public law, leading to the degree of Bachelor of Laws.

2. The College of Physicians and Surgeons, founded in 1807, offers a course of four years, in the principles and practice of medicine and surgery, leading to the degree of Doctor of Medicine.

3 The School of Mines, established in 1864, offers courses of study, each of four years, leading to a professional degree, in mining engineering and in metallurgy.

4. The schools of Chemistry, Engineering and Architecture, set off from the School of Mines in 1896, offer respectively, courses of study, each of four years, leading to an appropriate professional degree, in analytical and applied chemistry; in civil, sanitary, electrical and mechanical engineering; and in architecture.

5. Teachers College, founded in 1888 and chartered in 1889, was included in the University in 1898. It offers the following course of study: (*a*) graduate courses leading to the Master's and Doctor's diplomas in the several departments of the College; (*b*) professional courses, each of two years, leading to the Bachelor's diploma for Secondary Teaching, Elementary Teaching, Kindergarten, Domestic Art, Domestic Science, Fine Arts, Music, and Manual Training; (*c*) a collegiate course of two years, which is followed by a two-year professional course, leads to the degree of Bachelor of Science. Certain of its courses may be taken without extra charge, by students of the university in partial fulfillment of the requirements for degrees of Bachelor of Arts, Master of Arts and Doctor of Philosophy

6. College of Pharmacy founded in 1831 and included in the University in 1904. It offers courses of two years leading to appropriate degrees and diplomas.

The price of the University catalogue is twenty-five cents postpaid. Detailed information regarding the work in any department will be furnished without charge upon application to the *Secretary of Columbia University*, New York, N. Y.

Digitized by Google

The School of Mines Quarterly.

Journal of Applied Science

VOL. XXVII., 1905-6

NEW YORK CITY.

Subscription Price, $2.00 Per Annum, or 50 Cents Per Number.

All remittances should be made payable to order of "SCHOOL OF MINES QUARTERLY."

BOARD OF EDITORS.

A. J. MOSES, Adj. Prof. of Mineralogy.
J. F. KEMP, Prof. of Geology.
R. PEELE, Jr., Prof. of Mining.
E. WALLER, Analytical Chemist.
W. H. FREEDMAN, Electrical Engineer.
T. H. HARRINGTON, Tutor in Drawing.
R. E. MAYER, Adj. Prof. of Drawing

Managing Editor, R. E. MAYER.
Business Manager. T. H. HARRINGTON.

THE QUARTERLY is owned and managed by the ASSOCIATION of the ALUMNI of the SCHOOL OF MINES, COLUMBIA COLLEGE and while open to all, its pages are mainly filled by contributions from this great body of Specialists in Engineering, Mining, CHEMISTRY, METALLURGY GEOLOGY, MINERALOGY, etc. In this way it prints numerous valuable articles not elsewhere to be obtained. Careful abstracts of current literature of ANALYTICAL CHEMISTRY, METALLURGY and MINERALOGY appear regularly, and it is the expectation of the editors to extend this to other branches.

Fifty reprints will be sent ON REQUEST to each contributor without charge. If no request is made before the distribution of the type, it will be assumed that the reprints are not desired EXTRA reprints, title pages or covers will be furnished at the expense of the contributor.

See special notices regarding back numbers.

QUARTERLY REPRINTS.

The following covered pamphlet reprints may now be obtained for fifty cents.

The Theory and Design of the Masonry Arch, ... WM. H. BURR.
Alternating Current Laboratory Experiments and Commercial Tests, ... FITZHUGH TOWNSEND.
Engineering Tests on Direct Current Electrical Machinery, ... G. F. SEVER.

The following covered pamphlet reprints may now be obtained at twenty-five cents each:

No. 1. Stone Cutting, ... W. P. TROWBRIDGE.
No. 2. Parting Gold and Silver at the N. Y. Assay Office, ... T. EGLESTON.

The following pamphlet reprint may now be obtained for fifteen cents each:

Principles of Alternating Current Distribution, ... FRANCIS CROCKER.

THE SCHOOL OF MINES QUARTERLY, Columbia University, New York City.

Advertiser's Index.

	PAGE
American Gas Furnace Co.,	3
Atlantic, Gulf and Pacific Co.,	2d cover
Atlas Portland Cement Co.,	8
Audit Co. of N. Y.	6
Becker, Christian,	2
Berger & Sons, C. L.,	2
Buff & Buff Mfg. Co	5
Burnham, Williams & Co.,	2d cover
Columbia University,	10
Devoe & C. T. Raynolds Co.,	3
Dixon Crucible Co.,	2
Elmer & Amend,	9
Jeffrey Manufacturing Co.,	8
Jenkins Brothers,	"
Keasbey. Co. Robert A.,	4
Lidgerwood Mfg. Co.,	5
McIntosh, Seymour & Co.,	4
Montana Ore Purchasing Co.,	4
Morse Twist Drill & Machine Co.,	2d cover
Pryibil & Co.,	1
Roessler & Hasslacher Co.,	2
Sauveur, Albert	6
Sturtevant & Co., B. F.,	5
Vacuum Oil Co.,	5
Van Nostrand Co., D,	7
Weston Electrical Co.,	1
West Pulverizing Machine Co.,	6
Woodbridge School,	4th cover

Digitized by Google